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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 115.
L. O. HOWARD, Entomologist and Chief of Bureau.

# PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

## I. LIFE-HISTORY STUDIES ON THE CODLING MOTH IN MICHIGAN.

By A. G. HAMMAR, *Entomological Assistant,*
*Deciduous Fruit Insect Investigations.*

## II. THE ONE-SPRAY METHOD IN THE CONTROL OF THE CODLING MOTH AND THE PLUM CURCULIO. (SECOND REPORT.)

By A. L. QUAINTANCE, *In Charge of Deciduous Fruit Insect Investigations,*
AND
E. W. SCOTT, *Entomological Assistant.*

## III. LIFE-HISTORY OF THE CODLING MOTH IN THE SANTA CLARA VALLEY OF CALIFORNIA.

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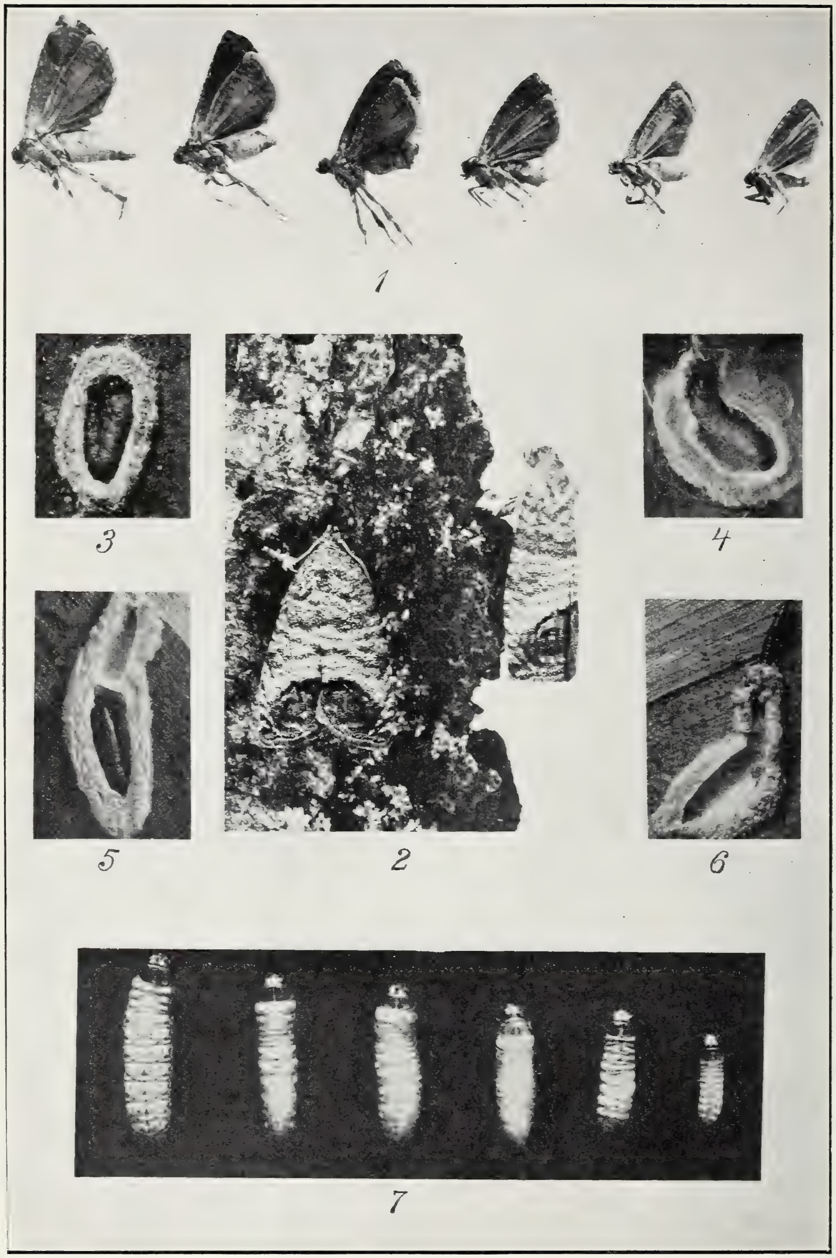
# ERRATA.

Page 1, after *Assistant*, replace period by comma.
Page 3, legend to figure 1, for *Emergency* read *Emergence.*
Page 32, legend to figure 1, after *Douglas* insert a comma.
Page 42, legend to Table XLII, for *emale* read *female.*
Page 161, line 20, for *Melachius* read *Malachius*.

PLATE I.



THE CODLING MOTH (CARPOCAPSA POMONELLA).

Fig. 1.—Variation in size of moths of the spring brood, twice enlarged. Fig. 2.—Two moths resting on the trunk of an apple tree, showing protective coloration; enlarged four times. Fig. 3.—Larva in winter cocoon. Fig. 4.—Larva in the act of remodeling the winter cocoon. Fig. 5.—Modified winter cocoon, with exit tube and silk partition. Fig. 6.—Cocoon after emergence of moth, enlarged. Fig. 7.—Variation in size of wintering larvæ, two and one-half times enlarged. Figs. 3-6 slightly enlarged. (Original.)

U. S. D. A., B. E. Bul. 115, Part I. D. F. I. I., August 9, 1912.

# PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

## LIFE-HISTORY STUDIES ON THE CODLING MOTH IN MICHIGAN.

By A. G. Hammar,
*Entomological Assistant. Deciduous Fruit Insect Investigations.*

### INTRODUCTION.

During the last four years the Bureau of Entomology has maintained a temporary field station at Douglas, Mich., for the purpose of investigating certain deciduous fruit insects. As a part of this work the present paper brings together the results for 1909, 1910, and 1911 of a detailed study of the life history of the codling moth (*Carpocapsa pomonella* L.). This investigation has been conducted on the general plan of the earlier work on this insect by the bureau as reported in 1909 by E. L. Jenne in the Ozarks and in 1910 by the writer in Pennsylvania.

During the season of 1909 the rearing work was carried out by Messrs. R. W. Braucher and W. Postiff; in 1910 and 1911 by the writer, assisted by Mr. E. R. van Leeuwen. In 1911 Mr. E. H. Siegler was also detailed to assist in the rearing work and has in addition aided the writer in the preparation of the manuscript tables. Mr. E. W. Scott, conducting various spraying experiments at the field station, has contributed valuable field observations. The writer wishes to express special thanks to many of the fruit growers of the Michigan fruit belt, who have facilitated this work both with valuable information and numerous courtesies, and to Prof. A. L. Quaintance, in charge of deciduous fruit insect investigations, whose practical suggestions throughout the course of this work have been of great aid.

A duplication of many rearing experiments for 1910 and 1911 became necessary because of the unprecedented seasonal condition during the spring of 1910, when the fruit crop was to a very great extent destroyed by the sudden alternations from warm to cold weather. The season of 1911 was very exceptional for its extreme heat, which is strikingly reflected in the rate of development of the insect during that year. The rearing work during the more normal season of 1909 was greatly limited owing to the stress of other work, and the rearing experiments for that season cover merely the more essential features of the life history of the codling moth. The results thus gathered under marked seasonal climatic variations become of particular value for comparative study, and through the duplication of certain rearing experiments better averages have been established for the time of occurrence and the duration of the separate stages of the insect.

## DEFINITION OF TERMS USED.

By the use of terms which are not well defined or uniformly interpreted confusion is often likely to arise. This is particularly true in regard to the terms "brood" and "generation" applied to the codling moth. In conformity with previous papers on the codling moth the term "brood" is here used in speaking of individuals of one generation of any stage, as egg, larva, or pupa. A "generation" is considered to begin with the egg stage and to terminate with the moth or imago stage of the same generation, thus including all the stages of a life cycle. Since the wintering larvæ of the codling moth in this section of the country are of both the first and the second broods, which can be separated only by rearing, they are all referred to as "wintering larvæ" or "wintering brood of larvæ."

Similarly, the pupæ and moths that result from the wintering larvæ and issue in the spring pertain also to the two broods. It may therefore be suitable to use the terms "spring brood of pupæ," and "spring brood of moths" or briefly "spring pupæ" and "spring moths." It should be remembered that the first brood of pupæ and the first brood of moths are actually second to appear during the season. For popular purposes to avoid confusion the latter set may be called "summer pupæ" and "summer moths" and in sections where three broods exist the second-brood pupæ and moths may be termed "fall pupæ" and "fall moths."

The following plan of designating the separate stages has been uniformly followed by the bureau in the codling moth investigations:

*The wintering larvæ* may include larvæ of the first, second, and third broods.

*The spring brood of pupæ* may include pupæ of the first, second, and third broods.

*The spring brood of moths* may include moths of the first, second, and third broods.

*The first generation* includes:

- *The first brood of eggs;*
- *The first brood of larvæ,* some of which winter;
- *The first brood of pupæ,* some of which transform the same season ("summer pupæ") and a part the following spring ("spring pupæ");
- *The first brood of moths,* some of which emerge the same season ("summer moths") and some the following spring ("spring moths").

*The second generation* includes:

*The second brood of eggs;*

*The second brood of larvæ,* all or only a part of which may winter;

*The second brood of pupæ,* of which a part may transform the same season ("fall pupæ"), and a part or all the following spring ("spring pupæ").

*The third generation* includes:

*The third brood of eggs;*

*The third brood of larvæ,* all of which winter as larvæ;

*The third brood of pupæ,* which transform the following spring ("spring pupæ");

*The third brood of moths,* which emerge the following spring ("spring moths").

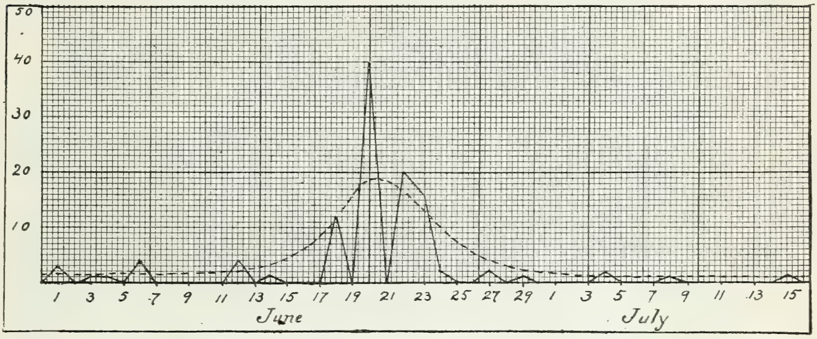


FIG. 1.—Emergency curve of spring brood of moths in 1909, at Douglas, Mich. Records of R. W. Braucher. (Original.)

## SEASONAL-HISTORY STUDIES OF 1909.

The records on the life history of the codling moth during 1909 cover merely the essential features and were all made by Messrs. R. W. Braucher and W. Postiff. The experiments were conducted in an outdoor rearing shelter, and inasmuch as the rearing material was from band-record collections the results should closely represent normal conditions.

### TIME OF EMERGENCE OF MOTHS OF THE SPRING BROOD.

In Table I and figure 1 is given the rate of emergence of 114 individual moths. The period for the maximum emergence is here well defined, occurring from June 17 to 24. Considering the limited number of insects used for this experiment it is very probable that isolated moths may have appeared even previous to June 1 and later than June 15, since the two broods of moths generally overlap.

TABLE I.—*Emergence of moths of the spring brood, Douglas, Mich., 1909.*

[Records by R. W. Braucher.]

| Date. | Number of moths. | Date. | Number of moths. | Date. | Number of moths. | Date. | Number of moths. |
|---|---|---|---|---|---|---|---|
| June 1 | 3 | June 13 | 1 | June 23 | 16 | July 8 | 1 |
| June 3 | 1 | June 16 | 3 | June 24 | 2 | Jul 15 | 1 |
| June 4 | 1 | June 18 | 12 | June 27 | 2 | | |
| June 6 | 4 | June 20 | 40 | June 29 | 1 | | |
| June 12 | 4 | June 22 | 20 | July 4 | 2 | | |

Total, 114 moths.

## TIME OF EMERGENCE OF MOTHS OF THE FIRST BROOD.

The earliest moth of the first brood emerged July 28 (Table II). It will be noted from the curve of figure 2 that the maximum of emergence occurred unusually early—August 3. Throughout the month of August there was a constant and large emergence. The great irregularity of the curve in figure 2 is largely due to the fact that the banded trees from which the rearing material was obtained were only examined once a week. However, certain of the irregularities of the curve are due to climatic influences.

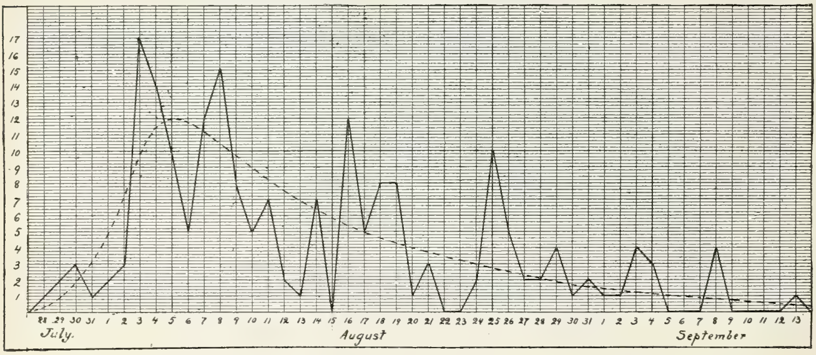


FIG. 2.—Emergence curve of first-brood moths in 1909, at Douglas, Mich. (Original.)

TABLE II.—*Emergence of moths of the first brood or summer brood at Douglas, Mich., 1909.*

[Records by W. Postiff.]

| Date. | Number of moths. | Date. | Number of moths. | Date. | Number of moths. | Date. | Number of moths. |
|---|---|---|---|---|---|---|---|
| July 28 | 1 | Aug. 8 | 15 | Aug. 19 | 8 | Aug. 30 | 1 |
| July 29 | 2 | Aug. 9 | 8 | Aug. 20 | 1 | Aug. 31 | 2 |
| July 30 | 3 | Aug. 10 | 5 | Aug. 21 | 3 | Sept. 1 | 1 |
| July 31 | 1 | Aug. 11 | 7 | Aug. 22 | .......... | Sept. 2 | 1 |
| Aug. 1 | 2 | Aug. 12 | 2 | Aug. 23 | .......... | Sept. 3 | 4 |
| Aug. 2 | 3 | Aug. 13 | 1 | Aug. 24 | 2 | Sept. 4 | 3 |
| Aug. 3 | 17 | Aug. 14 | 7 | Aug. 25 | 10 | Sept. 5 | .......... |
| Aug. 4 | 14 | Aug. 15 | .......... | Aug. 26 | 5 | Sept. 6 | .......... |
| Aug. 5 | 10 | Aug. 16 | 12 | Aug. 27 | 2 | Sept. 7 | .......... |
| Aug. 6 | 5 | Aug. 17 | 5 | Aug. 28 | 2 | Sept. 8 | 4 |
| Aug. 7 | 12 | Aug. 18 | 8 | Aug. 29 | 4 | Sept. 13 | 1 |

Total, 194 moths.

## BAND-RECORD EXPERIMENTS IN 1909.

In the band-record experiments of 1909, 30 apple trees were used, of which 15 trees were located in the yard of the laboratory and 16 trees in two near-by orchards. Fall and winter apples, such as Rhode Island Greening, Baldwin, Golden Russet, Northern Spy, Wealthy, etc., were used. With these late varieties of apple a thorough test was made of the relative abundance of first and second brood larvæ. The results of these experiments are recorded in Tables III and IV and by curves in figure 3.

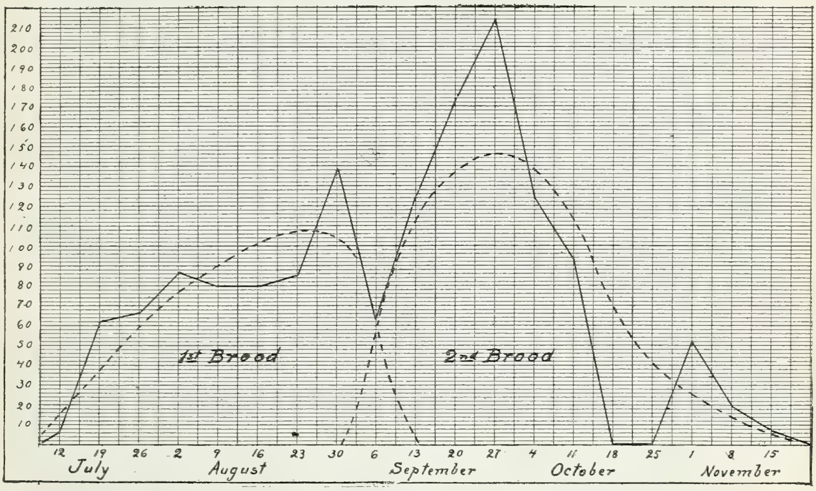


FIG. 3.—Curves showing maturity of larvæ of first and second broods; band-record curve, of 1909, at Douglas, Mich. (Original.)

TABLE III.—*Band-record experiments in 1909 at Douglas, Mich., by W. Postiff; completed in 1910 by A. G. Hammar.*

| No. of record. | Date of collecting. | Number of larvæ and pupæ. | Number of moths emerged, 1909. | Number of parasites, 1909. | Number of moths emerged, 1910. | Number of parasites, 1910. | Injured and winter-killed. |
|---|---|---|---|---|---|---|---|
| 1 | July 12 | 6 | 6 | .......... | .......... | .......... | .......... |
| 2 | July 19 | 62 | 49 | 4 | .......... | .......... | 9 |
| 3 | July 26 | 66 | 49 | 6 | .......... | .......... | 11 |
| 4 | Aug. 2 | 87 | 41 | 5 | 7 | 2 | 32 |
| 5 | Aug. 9 | 81 | 30 | 2 | 13 | 1 | 35 |
| 6 | Aug. 16 | 80 | 17 | .......... | 36 | 4 | 23 |
| 7 | Aug. 23 | 85 | 1 | .......... | 61 | 8 | 15 |
| 8 | Aug. 30 | 138 | 1 | .......... | 110 | 4 | 23 |
| 9 | Sept. 6 | 62 | .......... | .......... | 47 | 1 | 14 |
| 10 | Sept. 13 | 124 | .......... | .......... | 88 | 1 | 35 |
| 11 | Sept. 20 | 174 | .......... | .......... | 119 | 15 | 40 |
| 12 | Sept. 27 | 213 | .......... | .......... | 137 | 26 | 50 |
| 13 | Oct. 4 | 124 | .......... | .......... | 92 | 12 | 20 |
| 14 | Oct. 11 | 94 | .......... | .......... | 55 | 3 | 36 |
| 15 | Oct. 18 | .......... | .......... | .......... | .......... | .......... | .......... |
| 16 | Oct. 25 | .......... | .......... | .......... | .......... | .......... | .......... |
| 17 | Nov. 1 | 51 | .......... | .......... | 36 | 2 | 13 |
| 18 | Nov. 8 | 20 | .......... | .......... | 15 | 1 | 4 |
| 19 | Nov. 15 | 8 | .......... | .......... | 5 | .......... | 3 |
|  | Total.... | 1,475 | 194 | 17 | 821 | 80 | 363 |

Table IV.—*Summary of Table III; band-record experiments at Douglas, Mich., 1909.*

| Observations. | Total. | Per cent. | Observations. | Total. | Per cent. |
|---|---|---|---|---|---|
| Larvæ and pupæ collected from bands | 1,475 | 100.0 | Injured and winter-killed larvæ | 363 | 24.6 |
| Moths emerging: | | | Larvæ of the first brood | 636 | 43.1 |
| 1909 | 194 | 13.2 | Transforming larvæ of the first brood | 194 | 33.2 |
| 1910 | 821 | 55.7 | Wintering larvæ of the first brood | 425 | 66.8 |
| 1909–1910 | 1,015 | 68.8 | Larvæ of the second brood | 839 | 56.9 |
| Parasitized larvæ | 97 | 6.6 | | | |

In numbers the second brood of larvæ surpassed the first quite materially. From October 18 to 25 no larvæ were obtained, due to prevailing cold weather. However, during the exceptionally warm November quite a number were collected which under average seasons would have remained undeveloped. Of the first-brood larvæ 43 per cent transformed the same season, while 57 per cent wintered together with those of the second brood. Of the total number of larvæ, 6.58 per cent proved to be parasitized by a hymenopterous fly (*Ascogaster carpocapsæ* Vier.). The proportion winter-killed and injured by other causes was 24.6 per cent.

## SEASONAL-HISTORY STUDIES OF 1910.

The rearing material in the spring of 1910 consisted of an abundance of wintering larvae, which had been collected from banded trees during the previous season. During the winter and throughout the progress of the rearing experiments the insects were kept in cages in an outdoor shelter (see Plate II), and were thus exposed to the normal temperature conditions.

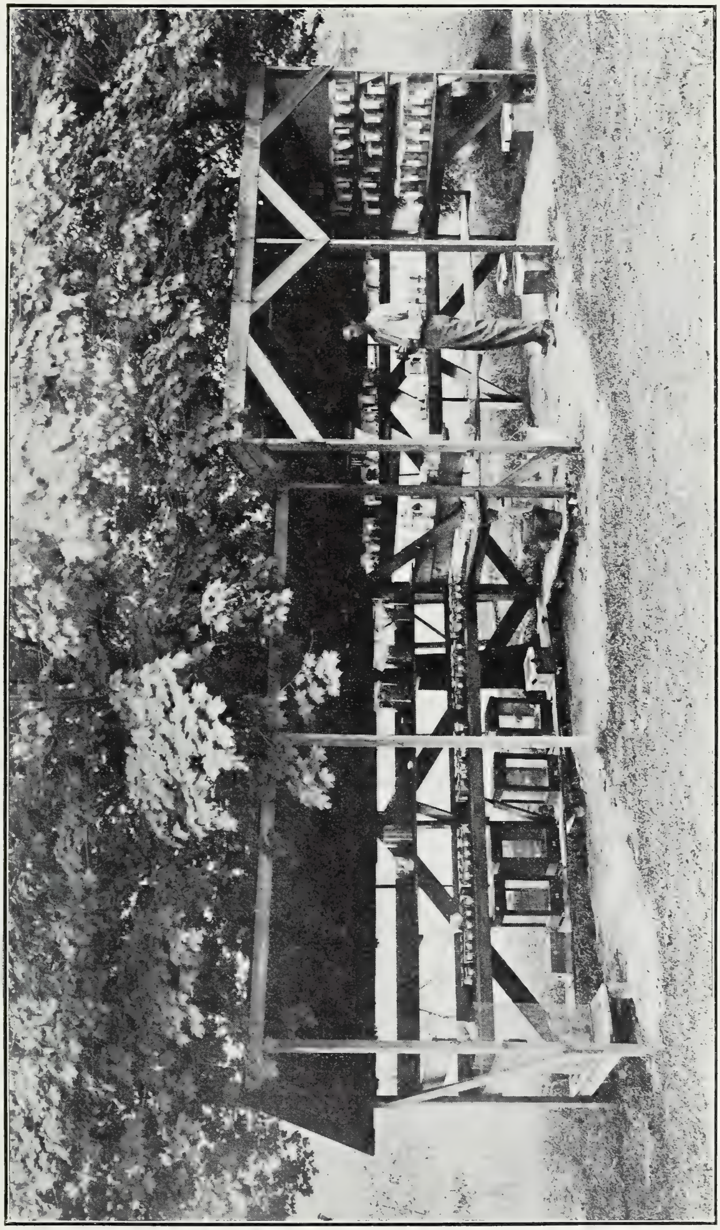
### WINTERING LARVÆ.

The wintering larvæ invariably consist of individuals of the two broods, as only a portion of the first brood transforms the same season to form the second generation of moths, while the other portion winters like all of the second-brood larvæ.

In the orchards a great number of the wintering larvæ find protection for their cocoons under the rough bark of the trees and in cracks and crevices in older trees, and many are frequently found imbedded in decayed wood. It is mainly in the latter places that the codling moth larvæ find an escape from woodpeckers and other birds which make persistent searches for the larvæ during the winter.

*The cocoon of the wintering larva.*—The winter cocoon of the larva is proportionately small and completely sealed, and consists of heavy walls for winter protection. In appearance these cocoons vary considerably, depending largely upon the place selected by the larvæ. Under loose bark, where the larvæ are not limited in space, the cocoons are more or less oval, as shown in Plate I, figure 3. A slight

PLATE II.



Outdoor Shelter Used in Rearing the Codling Moth in 1910 and 1911 at Douglas, Mich. (Original.)

depression is made in the bark, the walls along the exposed sides are constructed from fragments of bark held in place by silken threads, and the inside is finally lined with a thin layer of silk. Within the small space of the cocoon the larva will be found in a doubled-up position. In the spring, previous to pupation, the winter cocoon is partly remodeled by the larva (see Pl. I, fig. 4), and provision is made for the issuing moth by the construction of an exit tube (see Pl. I, fig. 5). This is partly made from fragments of the original wall of the cocoon and partly by the addition of new fragments of bark. Depending upon the location of the cocoon, the exit tube varies in length from one-fourth of an inch to over 1 inch. The purpose of the tube must be to provide a safe exit at the critical period of the emergence of the moth. Within the cocoon over the opening to the exit is placed a thin sheath of silk which is ruptured by the pupa at the time it wriggles out (see Pl. I, fig. 6) to give issuance to the moth.

The transforming larvæ of the first brood also make their cocoons with an exit tube. The cocoons of these larvæ, however, are only used for a short time and are hence of a more primitive construction.

*Variation in size of wintering larvæ.*—In size the wintering larvæ vary considerably (see Pl. I, fig. 7). There exists naturally a certain amount of individual variation, but in addition there are climatic factors which tend to increase this variation. The wintering larvæ of the first brood are for the most part fully developed. There seems to be a tendency for undersized larvæ to transform the same season, as if less fit to pass the winter. Of the second-brood larvæ there are always a number that fail to attain full growth in the fall, and others totally fail to enter hibernation before frost sets in. Larvæ parasitized by *Ascogaster carpocapsæ* are seldom more than half grown and lack the pink color of the healthy larva.

Judging from the uniformity of head measurements, the wintering larvæ, though variable in size, are probably to a great extent of the last or sixth instar. (See p. 78.)

*Winter-killed larvæ.*—In earlier studies of the codling moth the writer has noted that killing due to cold occurred more or less frequently among wintering larvæ. During the spring of 1910 and 1911 more definite data were obtained showing a rather high percentage of winter killing. Thus, of the total number of larvæ from the band records of 1909 (Tables III and IV), 27.6 per cent failed to develop. A mortality of about 4 per cent may be ascribed to injury from the handling of the insects, while the rest, 20 per cent, succumbed mainly to injury from cold. Under normal conditions in orchards the percentage of larvæ killed from cold is undoubtedly lower than the above figures because a proportionately large number is always destroyed during the winter by woodpeckers and nuthatches and in the spring, summer, and fall by predaceous insects and parasites.

It is quite noticeable that larvæ in exposed places or in poorly constructed cocoons are more frequently killed by cold than are those well protected.

As generally recommended under the control of the codling moth, it will be well worth while in orchards to eliminate the favorable hiding places of the larvæ, particularly the wintering brood. Such places are old stumps, decaying trunks, and branches of ill-kept trees, where cold weather little affects the larvæ or where their enemies can not readily reach them.

### SPRING BROOD OF PUPÆ.

*Methods of recording pupation.*—On account of the fact that pupation takes place within the cocoon it is often difficult to record this transformation without disturbing the insect by exposing the cocoon.

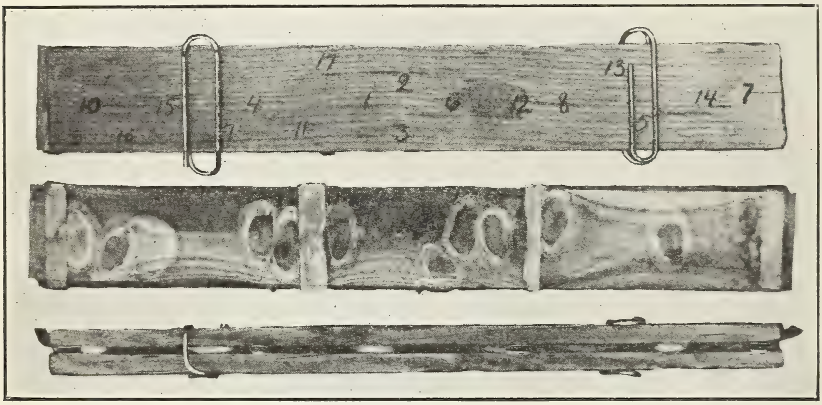


Fig. 4.—Device used in obtaining pupal records of the codling moth. (Original.)

Different workers have often used small glass vials, within which the larvæ have been compelled to make their cocoons and transform. This method is very unsatisfactory when we consider the habit of the larvæ under normal conditions. The larva, in the construction of the cocoon, either in cracks of wood or under the bark of trees, gnaws off a certain quantity of particles of wood or bark and from these the cocoon is largely made. Furthermore, under normal protection the larva suffers less from outside fluctuating temperatures than might be expected in a tube of glass.

Formerly the writer used soft strips of wood with narrow interspaces of one-eighth of an inch which the larvæ could enter and there spin their cocoons. To observe the larvæ and pupæ within it was necessary to pull the strips apart, thus exposing the cocoon. Later it was found that when a thin film of transparent celluloid was placed in the interspace so as to cover the wood on one side the larvæ produced their cocoons in a normal manner and at the same time left the side against the celluloid more or less uncovered, so that the insects could be observed within their cocoons without disturbing the latter. Some larvæ, however, particularly when exposed to too much light, would line with silk the side of the cocoon against the film. The difficulty in such cases was overcome by cutting in the film over the cocoon a small lobe or flap which could be gently lifted for the necessary exposure. This device is illustrated in figure 4. The upper figure shows the lower side with numbers corresponding to the position of the cocoons within. In the central figure several larvæ and cocoons are seen protected by the celluloid film. The two strips of wood are held together by a pair of common paper clips which have been bent and adjusted to the shape desired.

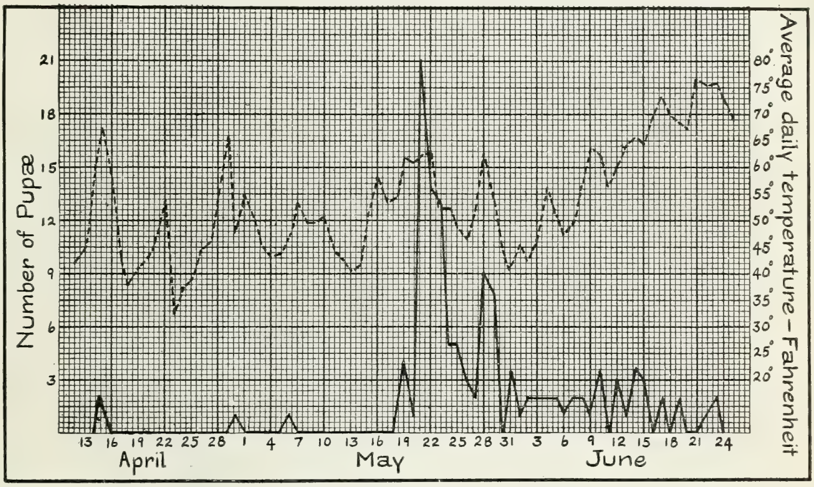


FIG. 5.—Diagram showing time of spring pupation of the codling moth in 1910, at Douglas, Mich. (Original.)

*Time of pupation.*—Owing to the very warm weather during the spring, pupation had commenced by April 15 (see fig. 5). However, with a change to cold weather that followed, pupation was interrupted until the latter part of May, and most of the larvæ pupated during the brief period from May 19 to May 31. The last pupa of this brood appeared on June 23. (See Table V.)

TABLE V.—*Pupation period for the codling moth in the spring of 1910, at Douglas, Mich.*

| No. of larvæ. | Date of pupation. | No. of larvæ. | Date of pupation. | No. of larvæ. | Date of pupation. | No. of larvæ. | Date of pupation. |
|---|---|---|---|---|---|---|---|
| 2 | Apr. 15 | 5 | May 25 | 2 | June 4 | 4 | June 14 |
| 1 | Apr. 30 | 3 | May 26 | 2 | June 5 | 3 | June 15 |
| 1 | May 6 | 2 | May 27 | 1 | June 6 | 2 | June 17 |
| 4 | May 19 | 9 | May 28 | 2 | June 7 | 2 | June 19 |
| 1 | May 20 | 8 | May 29 | 2 | June 8 | 1 | June 22 |
| 21 | May 21 | 4 | May 31 | 1 | June 9 | 2 | June 23 |
| 14 | May 22 | 1 | June 1 | 4 | June 10 | | |
| 13 | May 23 | 2 | June 2 | 3 | June 12 | | |
| 5 | May 24 | 2 | June 3 | 1 | June 13 | | |

*Length of spring pupal stage.*—The results of observations on the time of pupation and emergence of 106 individual insects are given in Table VI. Those pupating in April remained in this stage for the exceptionally long period of 59 days. The majority, pupating during the latter half of May, remained in the pupal stage about 30 days, while later larvæ, pupating about June 15, remained in this stage only 10 to 15 days. (See Table VI.) The average for the entire spring brood of pupæ was 26.02 days.

TABLE VI.—*Length of pupal stage of the spring brood, Douglas, Mich., 1910.*

| No. of observation. | Date of— | | Days. | No. of observation. | Date of— | | Days. |
|---|---|---|---|---|---|---|---|
| | Pupation. | Emergence. | | | Pupation. | Emergence. | |
| 1 | Apr. 15 | June 13 | 59 | 54 | May 25 | June 22 | 28 |
| 2 | Apr. 30 | June 15 | 46 | 55 | ...do | ...do | 28 |
| 3 | May 6 | June 17 | 42 | 56 | ...do | ...do | 28 |
| 4 | May 19 | June 18 | 30 | 57 | ...do | ...do | 28 |
| 5 | ...do | June 19 | 31 | 58 | ...do | June 23 | 29 |
| 6 | ...do | ...do | 31 | 59 | May 26 | June 22 | 27 |
| 7 | ...do | June 20 | 32 | 60 | ...do | ...do | 27 |
| 8 | May 20 | ...do | 31 | 61 | ...do | June 23 | 28 |
| 9 | May 21 | June 18 | 28 | 62 | May 27 | June 22 | 26 |
| 10 | ...do | June 19 | 29 | 63 | ...do | ...do | 26 |
| 11 | ...do | June 20 | 30 | 64 | May 28 | ...do | 25 |
| 12 | ...do | ...do | 30 | 65 | ...do | ...do | 25 |
| 13 | ...do | ...do | 30 | 66 | ...do | ...do | 25 |
| 14 | ...do | ...do | 30 | 67 | ...do | June 23 | 26 |
| 15 | ...do | ...do | 30 | 68 | ...do | ...do | 26 |
| 16 | ...do | ...do | 30 | 69 | ...do | ...do | 26 |
| 17 | ...do | ...do | 30 | 70 | ...do | ...do | 26 |
| 18 | ...do | June 21 | 31 | 71 | ...do | ...do | 26 |
| 19 | ...do | ...do | 31 | 72 | May 29 | June 19 | 21 |
| 20 | ...do | ...do | 31 | 73 | ...do | June 23 | 25 |
| 21 | ...do | ...do | 31 | 74 | ...do | ...do | 25 |
| 22 | ...do | ...do | 31 | 75 | ...do | ...do | 25 |
| 23 | ...do | ...do | 31 | 76 | ...do | ...do | 25 |
| 24 | ...do | ...do | 31 | 77 | May 31 | ...do | 23 |
| 25 | ...do | ...do | 31 | 78 | ...do | ...do | 23 |
| 26 | ...do | June 22 | 32 | 79 | June 1 | ...do | 22 |
| 27 | ...do | June 24 | 34 | 80 | June 2 | ...do | 21 |
| 28 | May 22 | June 21 | 30 | 81 | ...do | June 24 | 22 |
| 29 | ...do | ...do | 30 | 82 | June 3 | June 23 | 20 |
| 30 | ...do | ...do | 30 | 83 | ...do | June 24 | 21 |
| 31 | ...do | ...do | 30 | 84 | June 4 | June 23 | 19 |
| 32 | ...do | ...do | 30 | 85 | June 5 | ...do | 18 |
| 33 | ...do | ...do | 30 | 86 | ...do | ...do | 18 |
| 34 | ...do | ...do | 30 | 87 | June 6 | ...do | 17 |
| 35 | ...do | ...do | 30 | 88 | June 7 | June 24 | 17 |
| 36 | ...do | ...do | 30 | 89 | ...do | ...do | 17 |
| 37 | ...do | ...do | 30 | 90 | June 8 | ...do | 16 |
| 38 | ...do | June 22 | 31 | 91 | June 9 | June 25 | 16 |
| 39 | ...do | June 23 | 32 | 92 | June 10 | June 20 | 10 |
| 40 | ...do | ...do | 32 | 93 | ...do | June 24 | 14 |
| 41 | May 23 | June 21 | 29 | 94 | ...do | June 25 | 15 |
| 42 | ...do | ...do | 29 | 95 | ...do | June 26 | 16 |
| 43 | ...do | ...do | 29 | 96 | June 12 | ...do | 14 |
| 44 | ...do | June 22 | 30 | 97 | ...do | June 27 | 15 |
| 45 | ...do | ...do | 30 | 98 | ...do | ...do | 15 |
| 46 | ...do | ...do | 30 | 99 | June 13 | ...do | 14 |
| 47 | ...do | ...do | 30 | 100 | June 14 | June 28 | 14 |
| 48 | ...do | ...do | 30 | 101 | ...do | June 29 | 15 |
| 49 | ...do | ...do | 30 | 102 | June 15 | June 28 | 13 |
| 50 | ...do | ...do | 30 | 103 | ...do | June 29 | 14 |
| 51 | May 24 | ...do | 29 | 104 | June 17 | July 2 | 15 |
| 52 | ...do | ...do | 29 | 105 | June 19 | June 29 | 10 |
| 53 | ...do | June 28 | 35 | 106 | June 23 | July 8 | 15 |
| Average | | | | | | | 26.02 |
| Maximum | | | | | | | 59 |
| Minimum | | | | | | | 10 |

TABLE VII.—*Length of pupal stage of the spring brood, Douglas, Mich., 1910; summary of Table VI.*

| Number of observations. | Pupal period. | Number of observations. | Pupal period. | Number of observations. | Pupal period. | Number of observations. | Pupal period. |
|---|---|---|---|---|---|---|---|
| | *Days.* | | *Days.* | | *Days.* | | *Days.* |
| 2 | 10 | 1 | 19 | 2 | 27 | 1 | 35 |
| 1 | 13 | 1 | 20 | 6 | 28 | 1 | 42 |
| 5 | 14 | 3 | 21 | 7 | 29 | 1 | 46 |
| 6 | 15 | 2 | 22 | 25 | 30 | 1 | 59 |
| 3 | 16 | 2 | 23 | 12 | 31 | | |
| 3 | 17 | 7 | 25 | 4 | 32 | | |
| 2 | 18 | 7 | 26 | 1 | 34 | | |

## SPRING BROOD OF MOTHS.

*Time of emergence* (fig. 6, p. 12).—Notwithstanding the changeable weather conditions during the spring of 1910 the codling moths emerged with striking uniformity. The earliest moth in the rearing cages appeared June 13; the great majority of moths emerged between June 18 and June 30; isolated moths continued to appear up to the close of July, when the first moths of the summer brood commenced to issue. The maximum emergence took place June 22. The emergence for the spring brood is given in Table VIII.

TABLE VIII.—*Time of emergence of the spring brood of moths during 1910, at Douglas, Mich.*

| Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. |
|---|---|---|---|---|---|---|---|
| 5 | June 13 | 59 | June 25 | 7 | July 7 | ........ | July 19 |
| 5 | June 14 | 56 | June 26 | 6 | July 8 | ........ | July 20 |
| 1 | June 15 | 81 | June 27 | 6 | July 9 | 2 | July 21 |
| 4 | June 16 | 36 | June 28 | 0 | July 10 | ........ | July 22 |
| 17 | June 17 | 45 | June 29 | 5 | July 11 | 1 | July 23 |
| 40 | June 18 | 53 | June 30 | 8 | July 12 | ........ | July 24 |
| 52 | June 19 | 33 | July 1 | ........ | July 13 | ........ | July 25 |
| 82 | June 20 | 34 | July 2 | 6 | July 14 | ........ | July 26 |
| 162 | June 21 | 19 | July 3 | ........ | July 15 | 2 | July 27 |
| 232 | June 22 | 9 | July 4 | ........ | July 16 | | |
| 199 | June 23 | 10 | July 5 | 6 | July 17 | | |
| 128 | June 24 | 10 | July 6 | ........ | July 18 | | |

*Variation in size of moths of the spring brood.*—The moths of the spring brood vary considerably in size and to a greater extent than do those of the summer brood. (See Pl. I, fig. 1.) This might be expected on considering the difference in size of the wintering larvæ from which the moths result.

There have often appeared dwarfed specimens of moths from the band-record material which at first sight could hardly be recognized to be of the codling-moth species. That there should exist a corresponding difference in the vitality of individual moths is only natural and is fully reflected in many of the results of the rearing experiments. In view of the great variability in behavior of the insect it has been necessary to conduct many of the experiments on a large scale in order to establish reliable averages.

*Time of oviposition.*—The time of oviposition in orchards may be determined with fair precision from the combined data on the habits of the moths in captivity, the rearing experiments, and the field observations. In rearing these insects eggs may be readily obtained by confining a number of moths together in cages. It is not possible to determine the number of eggs thus produced, but the time and period of egg deposition can be ascertained.

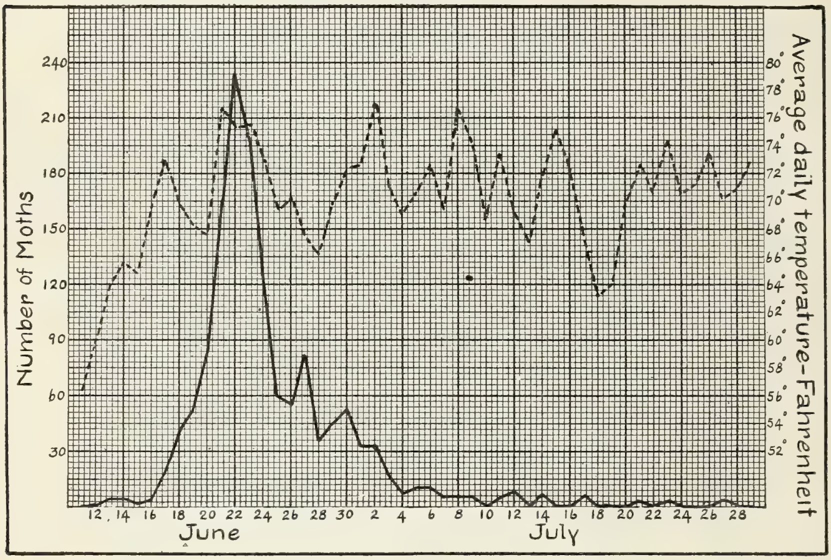


FIG. 6.—Emergence curve of spring brood of moths in 1910, at Douglas, Mich. (Original.)

TABLE IX.—*Egg deposition of the spring brood of moths in cages in 1910, at Douglas, Mich.*

| No. of cage. | Number of moths. | Date of— Emergence. | Date of— First oviposition. | Date of— Last oviposition. | Number of days— Before first oviposition. | Number of days— Of egg deposition. | Number of days— From date of emergence to last oviposition. |
|---|---|---|---|---|---|---|---|
| 1 | 5 | June 14 | June 19 | June 21 | 5 | 3 | 7 |
| 2 | 3 | June 16 | June 20 | .....do..... | 4 | 2 | 5 |
| 3 | 15 | June 17 | June 19 | June 25 | 2 | 7 | 8 |
| 4 | 36 | June 18 | June 20 | June 26 | 2 | 7 | 8 |
| 5 | 57 | June 19 | .....do..... | June 27 | 1 | 8 | 8 |
| 6 | 87 | June 20 | June 23 | June 29 | 3 | 7 | 9 |
| 7 | 262 | June 22 | .....do..... | July 4 | 1 | 12 | 12 |
| 8 | 25 | June 24 | June 29 | July 2 | 5 | 4 | 8 |
| 9 | 29 | June 25 | .....do..... | July 10 | 4 | 12 | 15 |
| 10 | 27 | June 27 | July 2 | July 7 | 5 | 6 | 10 |
| 11 | 16 | June 28 | July 1 | July 3 | 3 | 3 | 5 |
| 12 | 24 | June 29 | July 2 | July 10 | 3 | 9 | 11 |
| 13 | 36 | June 30 | July 3 | July 9 | 3 | 7 | 9 |
| 14 | 25 | July 2 | July 9 | .....do..... | 7 | 1 | 7 |
| 15 | 8 | July 6 | July 8 | July 11 | 2 | 4 | 5 |
| 16 | 5 | July 9 | July 11 | .....do..... | 2 | 1 | 2 |
| 17 | 5 | July 11 | July 14 | July 14 | 3 | 1 | 3 |
| Average number of days |  |  |  |  | 3.24 | 5.53 | 7.76 |
| Maximum number of days |  |  |  |  | 7 | 12 | 15 |
| Minimum number of days |  |  |  |  | 1 | 1 | 2 |

In Table IX are given the results from 17 separate "stock-jar" experiments, so called because of the nature of these experiments. Medium-sized glass jars of about 1 gallon capacity were found to be well suited for the purpose. To provide for a certain amount of moisture a layer of damp sand was put in each jar; food was furnished the moths in the form of diluted sugar and honey solution placed on a small piece of sponge. In each cage a certain number of moths, of known date of emergence, was confined, and throughout the course of the experiments a daily record was kept of egg deposition and the length of life of the moths. The eggs were laid indiscriminately all over the cage, on the sand, on the sides of the glass, on apple foliage and fruit, and on the cloth cover of the jars. When too many moths were confined together eggs were even placed on the wings and backs of some of the moths. For the purpose of recording the egg stage it was found desirable to have the moths oviposit on pear leaves in place of fruit because the leaves darken upon withering, so that the light-colored semitransparent eggs may be better observed. Each day fresh foliage was placed in the cages, which insured eggs of a given date of deposition.

On an average the moths commenced to oviposit three days after the date of emergence and most of the eggs were laid within a week of emergence. In a few extreme cases eggs were laid the second day after emergence. In one instance the last eggs were laid 15 days after the date of emergence. (See Table IX.) Several moths in the stock jars survived from 19 to 25 days.

*Length of life of moths.*—A summary of observations on the life of 529 moths is given in Tables X and XI. The average length of life was 9.44 days, the maximum 25 days, and the minimum 2 days. These moths were from the stock-jar experiments previously described.

TABLE X.—*Summary of observations on the length of life of 529 moths of the spring brood in confinement, Douglas, Mich., 1910.*

| Number of moths. | Number of days. | Number of moths. | Number of days. | Number of moths. | Number of days. | Number of moths. | Number of days. |
|---|---|---|---|---|---|---|---|
| 8 | 2 | 118 | 8 | 60 | 13 | 9 | 18 |
| 1 | 3 | 16 | 9 | 14 | 14 | 6 | 19 |
| 8 | 5 | 47 | 10 | 7 | 15 | 1 | 20 |
| 74 | 6 | 28 | 11 | 9 | 16 | 1 | 25 |
| 70 | 7 | 44 | 12 | 8 | 17 | | |

TABLE XI.—*Summary of Table X. Length of life of moths of the spring brood, 1910.*

| | Days alive. |
|---|---|
| Average | 9.44 |
| Maximum | 25 |
| Minimum | 2 |

## THE FIRST GENERATION.

### FIRST BROOD OF EGGS.

*Length of incubation.*—The eggs of the first brood on an average hatched within 6 or 7 days. Under low temperature the maximum length of time was 10 days. The shortest period of incubation was 4 days. (See Table XII.)

TABLE XII.—*Incubation period of eggs of the first brood laid in rearing cages, Douglas, Mich., 1910.*

| No. of observation. | Date of egg deposition. | Date of— | | | Duration of— | | |
|---|---|---|---|---|---|---|---|
| | | Appearance of red ring. | Appearance of black spot. | Hatching. | Red ring. | Black spot. | Incubation. |
| | | | | | *Days.* | *Days.* | *Days.* |
| 1 | June 20 | | | June 29 | | | 9 |
| 2 | do | | | June 30 | | | 10 |
| 3 | June 22 | | June 28 | June 29 | | 6 | 7 |
| 4 | do | | do | June 30 | | 6 | 8 |
| 5 | June 24 | | | July 1 | | | 7 |
| 6 | June 25 | | | July 2 | | | 7 |
| 7 | June 26 | | | do | | | 6 |
| 8 | June 27 | | | July 3 | | | 6 |
| 9 | June 28 | | | July 4 | | | 6 |
| 10 | do | | | July 5 | | | 7 |
| 11 | June 29 | | July 3 | July 4 | | 4 | 5 |
| 12 | do | | do | July 5 | | 4 | 6 |
| 13 | June 30 | July 3 | July 5 | July 6 | 3 | 5 | 6 |
| 14 | do | do | do | July 7 | 3 | 5 | 7 |
| 15 | July 1 | do | July 6 | do | 2 | 5 | 6 |
| 16 | do | do | do | July 8 | 2 | 5 | 7 |
| 17 | July 2 | July 5 | July 7 | do | 3 | 5 | 6 |
| 18 | July 3 | July 6 | July 8 | July 9 | 3 | 5 | 6 |
| 19 | do | do | do | July 10 | 3 | 5 | 7 |
| 20 | July 4 | do | July 9 | do | 2 | 5 | 6 |
| 21 | do | do | July 10 | July 12 | 2 | 6 | 8 |
| 22 | July 6 | July 9 | July 11 | July 13 | 3 | 5 | 7 |
| 23 | do | do | do | July 14 | 3 | 5 | 8 |
| 24 | July 7 | do | do | July 13 | 2 | 4 | 6 |
| 25 | July 8 | July 10 | July 12 | July 14 | 2 | 4 | 6 |
| 26 | July 9 | July 12 | July 14 | July 15 | 3 | 5 | 6 |
| 27 | do | July 13 | do | July 16 | 4 | 5 | 7 |
| 28 | July 12 | July 14 | July 15 | do | 2 | 3 | 4 |
| 29 | do | do | do | July 17 | 2 | 3 | 5 |
| 30 | do | do | July 16 | July 18 | 2 | 4 | 6 |
| Average | | | | | 2.5 | 4.7 | 6.6 |
| Maximum | | | | | 4 | 6 | 10 |
| Minimum | | | | | 2 | 3 | 4 |

The so-called "red ring" of the egg appeared from two to three days after egg deposition, and the "black spot" from one to two days previous to hatching.

The eggs used in these experiments were laid in cages on pear foliage. Records on the development of the eggs were taken once daily between 9 and 10 o'clock in the morning.

### FIRST BROOD OF LARVÆ.

*Time of hatching.*—In the field the actual time of hatching and the relative abundance of newly hatched larvæ may be fairly well determined from the different data on hand relative to the time of emergence of the moths, egg deposition, incubation of eggs, length of feeding of larvæ, and the appearance of mature larvæ, as shown by the band records. In correlating these facts the time of hatching is established as given in the diagram of figure 11.

The earliest eggs were deposited June 17, the maximum oviposition was reached at the close of June, and a few late eggs were laid up to the end of July. Incubation of the earliest eggs lasted nine days; for eggs laid about June 30, six days; and for later ones laid during the middle and latter part of July, only four to five days. The larvæ from the Saugatuck band records (fig. 9) reach a maximum July 31, and inasmuch as the average length of feeding for this brood of larvæ was 27 days the date for the maximum hatching would be July 4. On the other hand, on the basis of oviposition and length of incubation the height of the hatching period would be July 6.

*Length of feeding.*—Reference has already been made in the previous pages to the fact that a portion of the first-brood larvæ do not transform the same year, but winter and complete the life cycle the following year. The transforming and wintering larvæ differ in the length of feeding, and the latter are often materially larger in size. Thus on an average the transforming larvæ remained in the fruit 25 days against 29 days for the wintering larvæ. (See Tables XVI and XVII.) For the entire brood of larvæ the shortest feeding period was 17 days, the longest 45 days.

*Time of maturity of larvæ.*—In the field the time of maturity of the larvæ is determined from the band-record experiments (fig. 9 and Table XXVIII). Thus the period for the first-brood larvæ at Douglas, Mich., extended from July 10 to September 10. After the emergence of the moths from the band-record collection it may further be possible to determine the time of maturity of transforming and wintering larvæ of this brood. The last transforming larva left the fruit August 8 and the first wintering larvæ left the fruit July 20. There is also a difference in the appearance of cocoons whereby the two sets of larvæ may be recognized; the transforming larva provides the cocoon with an exit tube, while the wintering larva produces a closed cocoon. (For full description see pp. 6–7.)

*Percentages of transforming and wintering larvæ.*—From Table XXXI it will be found that 201 larvæ of the first brood transformed the same season, while 368 wintered, or 35 per cent transformed and 64.1 per cent wintered.

Somewhat similar results were obtained from the rearing experiments, though these can not be as reliable as the data from the band-record experiments, since the former are from a limited number of observations. Out of a total of 51 larvæ, 21 transformed and 30 wintered, or 40 per cent transformed and 60 per cent wintered. (See Table XXII.)

*Larval life in the cocoon.*—The length of time required for the making of the cocoon depends largely upon whether the larva is to transform the same season or to winter. A slight individual variation of time naturally does exist for either set of larvæ. In case of wintering larvæ it is difficult to decide just when the cocoon is completed. The transforming larvæ cease to be active from two to three days before pupating. For these, then, the larval life in the cocoon can be readily determined, being considered as the period from the time of leaving the fruit to the time of pupation.

In Table XIII are given the results from observations on 117 individual insects. Further records on the same topic are found in Table XVI. The larval life in the cocoon varied from 3 to 15 days with an average of 7 days. In case of a very short period of from 3 to 5 days the larvæ abandoned its first cocoon and made a new one. The records, however, only show the time consumed for the making of the last cocoon. Such cocoons are very primitive in appearance and have not been completed.

TABLE XIII.—*Length of the pupal stage of the first brood, Douglas, Mich., 1910.*

| No. of observation. | Date of— | | | Larvæ in cocoon. | Pupal period. | No. of observation. | Date of— | | | Larvæ in cocoon. | Pupal period. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Leaving fruit. | Pupation. | Emergence. | | | | Leaving fruit. | Pupation. | Emergence. | | |
| | | | | *Days.* | *Days.* | | | | | *Days.* | *Days.* |
| 1 | July 22 | July 25 | Aug. 9 | 3 | 15 | 60 | July 29 | Aug. 4 | Aug. 20 | 6 | 16 |
| 2 | ...do.... | July 26 | ...do.... | 4 | 14 | 61 | July 30 | ...do.... | Aug. 17 | 5 | 13 |
| 3 | ...do.... | ...do.... | ...do.... | 4 | 14 | 62 | ...do.... | ...do.... | ...do.... | 5 | 13 |
| 4 | ...do.... | ...do.... | ...do.... | 4 | 14 | 63 | ...do.... | ...do.... | ...do.... | 5 | 13 |
| 5 | ...do.... | ...do.... | Aug. 13 | 4 | 18 | 64 | ...do.... | ...do.... | Aug. 18 | 5 | 14 |
| 6 | ...do.... | ...do.... | Aug. 15 | 4 | 20 | 65 | ...do.... | ...do.... | ...do.... | 5 | 14 |
| 7 | ...do.... | ...do.... | ...do.... | 4 | 20 | 66 | ...do.... | ...do.... | ...do.... | 5 | 14 |
| 8 | ...do.... | ...do.... | Aug. 20 | 4 | 25 | 67 | ...do.... | ...do.... | ...do.... | 5 | 14 |
| 9 | ...do.... | Aug. 6 | Aug. 19 | 15 | 13 | 68 | ...do.... | ...do.... | Aug. 19 | 5 | 15 |
| 10 | ...do.... | ...do.... | Aug. 20 | 15 | 14 | 69 | ...do.... | ...do.... | Aug. 21 | 5 | 17 |
| 11 | July 23 | July 29 | Aug. 13 | 6 | 15 | 70 | ...do.... | Aug. 5 | Aug. 18 | 6 | 13 |
| 12 | ...do.... | Aug. 4 | Aug. 17 | 12 | 13 | 71 | ...do.... | Aug. 6 | ...do.... | 7 | 12 |
| 13 | ...do.... | ...do.... | ...do.... | 12 | 13 | 72 | ...do.... | ...do.... | Aug. 21 | 7 | 15 |
| 14 | July 25 | July 30 | Aug. 15 | 5 | 16 | 73 | ...do.... | Aug. 7 | Aug. 18 | 8 | 11 |
| 15 | ...do.... | Aug. 1 | ...do.... | 7 | 14 | 74 | ...do.... | Aug. 9 | Aug. 21 | 10 | 12 |
| 16 | ...do.... | Aug. 3 | ...do.... | 9 | 12 | 75 | ...do.... | ...do.... | ...do.... | 10 | 12 |
| 17 | ...do.... | ...do.... | ...do.... | 9 | 12 | 76 | ...do.... | ...do.... | ...do.... | 10 | 12 |
| 18 | ...do.... | ...do.... | Aug. 16 | 9 | 13 | 77 | ...do.... | ...do.... | Aug. 24 | 10 | 15 |
| 19 | ...do.... | ...do.... | ...do.... | 9 | 13 | 78 | July 31 | Aug. 4 | Aug. 17 | 4 | 13 |
| 20 | July 26 | ...do.... | ...do.... | 8 | 13 | 79 | ...do.... | ...do.... | ...do.... | 4 | 13 |
| 21 | ...do.... | ...do.... | ...do.... | 8 | 13 | 80 | ...do.... | ...do.... | Aug. 18 | 4 | 14 |
| 22 | ...do.... | ...do.... | ...do.... | 8 | 13 | 81 | ...do.... | Aug. 5 | ...do.... | 5 | 13 |
| 23 | ...do.... | ...do.... | ...do.... | 8 | 13 | 82 | ...do.... | Aug. 6 | Aug. 19 | 6 | 13 |
| 24 | ...do.... | ...do.... | ...do.... | 8 | 13 | 83 | ...do.... | ...do.... | Aug. 20 | 6 | 14 |
| 25 | ...do.... | ...do.... | Aug. 18 | 8 | 15 | 84 | ...do.... | Aug. 7 | ...do.... | 7 | 13 |
| 26 | ...do.... | Aug. 4 | Aug. 17 | 9 | 13 | 85 | ...do.... | ...do.... | Aug. 21 | 7 | 14 |
| 27 | July 27 | Aug. 3 | Aug. 13 | 7 | 10 | 86 | ...do.... | Aug. 9 | Aug. 22 | 9 | 13 |
| 28 | ...do.... | ...do.... | Aug. 15 | 7 | 12 | 87 | ...do.... | ...do.... | ...do.... | 9 | 13 |
| 29 | ...do.... | ...do.... | ...do.... | 7 | 12 | 88 | Aug. 1 | Aug. 4 | Aug. 18 | 3 | 14 |
| 30 | ...do.... | ...do.... | ...do.... | 7 | 12 | 89 | ...do.... | Aug. 5 | Aug. 19 | 4 | 14 |
| 31 | ...do.... | ...do.... | ...do.... | 7 | 12 | 90 | ...do.... | Aug. 6 | Aug. 18 | 5 | 12 |
| 32 | ...do.... | ...do.... | Aug. 16 | 7 | 13 | 91 | ...do.... | ...do.... | Aug. 19 | 5 | 13 |
| 33 | ...do.... | ...do.... | ...do.... | 7 | 13 | 92 | ...do.... | ...do.... | Aug. 20 | 5 | 14 |
| 34 | ...do.... | ...do.... | ...do.... | 7 | 13 | 93 | ...do.... | ...do.... | ...do.... | 5 | 14 |
| 35 | ...do.... | ...do.... | Aug. 18 | 7 | 15 | 94 | ...do.... | ...do.... | ...do.... | 5 | 14 |
| 36 | ...do.... | ...do.... | ...do.... | 7 | 15 | 95 | ...do.... | Aug. 8 | Aug. 21 | 7 | 13 |
| 37 | ...do.... | Aug. 4 | Aug. 15 | 8 | 11 | 96 | ...do.... | Aug. 9 | ...do.... | 8 | 12 |
| 38 | ...do.... | ...do.... | Aug. 18 | 8 | 14 | 97 | ...do.... | ...do.... | Aug. 22 | 8 | 13 |
| 39 | ...do.... | Aug. 6 | Aug. 20 | 10 | 14 | 98 | Aug. 4 | Aug. 12 | ...do.... | 8 | 10 |
| 40 | July 28 | Aug. 3 | Aug. 15 | 6 | 12 | 99 | ...do.... | Aug. 13 | Aug. 25 | 9 | 12 |
| 41 | ...do.... | ...do.... | Aug. 16 | 6 | 13 | 100 | ...do.... | Aug. 14 | Aug. 26 | 10 | 12 |
| 42 | ...do.... | ...do.... | ...do.... | 6 | 13 | 101 | ...do.... | Aug. 15 | Aug. 29 | 11 | 14 |
| 43 | ...do.... | ...do.... | Aug. 17 | 6 | 14 | 102 | ...do.... | ...do.... | Aug. 30 | 11 | 15 |
| 44 | ...do.... | Aug. 4 | ...do.... | 7 | 13 | 103 | Aug. 5 | Aug. 13 | Aug. 24 | 8 | 11 |
| 45 | ...do.... | ...do.... | ...do.... | 7 | 13 | 104 | ...do.... | Aug. 14 | Aug. 25 | 9 | 11 |
| 46 | ...do.... | ...do.... | ...do.... | 7 | 13 | 105 | ...do.... | Aug. 17 | Aug. 30 | 12 | 13 |
| 47 | ...do.... | ...do.... | Aug. 18 | 7 | 14 | 106 | Aug. 7 | Aug. 15 | Aug. 27 | 8 | 12 |
| 48 | ...do.... | ...do.... | ...do.... | 7 | 14 | 107 | Aug. 8 | Aug. 14 | Aug. 25 | 6 | 11 |
| 49 | ...do.... | ...do.... | ...do.... | 7 | 14 | 108 | ...do.... | Aug. 15 | Aug. 24 | 7 | 9 |
| 50 | ...do.... | ...do.... | ...do.... | 7 | 14 | 109 | ...do.... | Aug. 16 | Aug. 30 | 8 | 14 |
| 51 | ...do.... | Aug. 5 | Aug. 19 | 8 | 14 | 110 | ...do.... | Aug. 17 | Sept. 1 | 9 | 15 |
| 52 | ...do.... | ...do.... | ...do.... | 8 | 14 | 111 | ...do.... | ...do.... | ...do.... | 9 | 15 |
| 53 | ...do.... | Aug. 9 | Aug. 22 | 12 | 13 | 112 | Aug. 9 | Aug. 15 | Aug. 26 | 6 | 11 |
| 54 | July 29 | Aug. 3 | Aug. 16 | 5 | 13 | 113 | ...do.... | Aug. 16 | Aug. 30 | 7 | 14 |
| 55 | ...do.... | ...do.... | ...do.... | 5 | 13 | 114 | Aug. 10 | Aug. 15 | Aug. 29 | 5 | 14 |
| 56 | ...do.... | Aug. 4 | Aug. 17 | 6 | 13 | 115 | Aug. 16 | Aug. 25 | Sept. 14 | 9 | 20 |
| 57 | ...do.... | ...do.... | Aug. 18 | 6 | 14 | 116 | ...do.... | ...do.... | ...do.... | 9 | 20 |
| 58 | ...do.... | ...do.... | ...do.... | 6 | 14 | 117 | ...do.... | Aug. 26 | ...do.... | 10 | 19 |
| 59 | ...do.... | ...do.... | ...do.... | 6 | 14 | | | | | | |
| Average | | | | | | | | | | 7.1 | 13.6 |
| Maximum | | | | | | | | | | 15 | 25 |
| Minimum | | | | | | | | | | 3 | 9 |

### FIRST BROOD OF PUPÆ OR SUMMER PUPÆ.

*Time of pupation.*—The time of pupation may be determined from the records of the pupal stage and the emergence of moths of the same brood (see fig. 11) since it is to be expected that the rate of pupation approximates that of the emergence of the moths resulting from these pupæ.

TABLE XIV.—*Length of the pupal stage of the first brood, Douglas, Mich., 1910; summary of Table XIII.*

| Number of observations. | Larvæ in cocoon. | Number of observations. | Pupal period. |
|---|---|---|---|
| | *Days.* | | *Days.* |
| 2 | 3 | 1 | 9 |
| 11 | 4 | 2 | 10 |
| 19 | 5 | 6 | 11 |
| 15 | 6 | 16 | 12 |
| 25 | 7 | 38 | 13 |
| 17 | 8 | 33 | 14 |
| 13 | 9 | 11 | 15 |
| 7 | 10 | 2 | 16 |
| 2 | 11 | 1 | 17 |
| 4 | 12 | 1 | 18 |
| 2 | 15 | 1 | 19 |
| | | 4 | 20 |
| | | 1 | 25 |

*Length of pupal stage* (Tables XIII and XIV).—The pupal stage of the first brood varied from 9 to 25 days with an average of 13.6 days. The experiments of Table XIII include observations taken during the greater part of the pupal period.

TABLE XV.—*Time of emergence of moths of the summer brood from band-collected material of 1910.*

| Date of emergence. | Number of moths from band records at— | | | | Date of emergence. | Number of moths from band records at— | | | |
|---|---|---|---|---|---|---|---|---|---|
| | New Richmond. | Saugatuck. | Lake Shore. | Total. | | New Richmond. | Saugatuck. | Lake Shore. | Total. |
| July 26 | 2 | ........ | ........ | 2 | Aug. 16 | 5 | 14 | 12 | 31 |
| July 27 | 2 | ........ | ........ | 2 | Aug. 17 | 3 | 10 | 12 | 25 |
| July 28 | 4 | ........ | 6 | 10 | Aug. 18 | 4 | 3 | 13 | 20 |
| July 29 | 4 | 1 | 6 | 11 | Aug. 19 | 2 | 11 | 10 | 23 |
| July 30 | 4 | ........ | 4 | 8 | Aug. 20 | 6 | 9 | 10 | 25 |
| July 31 | 7 | 2 | ........ | 9 | Aug. 21 | ........ | 10 | 8 | 18 |
| Aug. 1 | 9 | 5 | 14 | 28 | Aug. 22 | 8 | 21 | 28 | 57 |
| Aug 2 | 2 | 16 | 7 | 25 | Aug. 23 | 3 | 8 | 5 | 16 |
| Aug. 3 | 7 | 8 | 10 | 25 | Aug. 24 | ........ | 6 | 9 | 15 |
| Aug. 4 | 4 | 3 | 6 | 13 | Aug. 25 | ........ | 6 | 4 | 10 |
| Aug. 5 | 1 | 4 | 3 | 8 | Aug. 26 | ........ | 5 | ........ | 5 |
| Aug. 6 | 11 | 5 | 8 | 24 | Aug. 27 | 2 | ........ | 6 | 8 |
| Aug. 7 | 6 | 4 | 3 | 13 | Aug. 28 | ........ | 5 | ........ | 5 |
| Aug. 8 | 12 | 4 | 8 | 24 | Aug. 29 | ........ | 1 | 5 | 6 |
| Aug. 9 | 10 | 4 | 9 | 23 | Aug. 30 | 1 | 2 | 2 | 5 |
| Aug. 10 | 3 | 9 | 6 | 18 | Aug. 31 | 1 | ........ | 1 | 2 |
| Aug. 11 | 6 | 1 | 5 | 12 | Sept. 1 | 1 | ........ | ........ | 1 |
| Aug. 12 | 6 | 1 | 7 | 14 | Sept. 7 | ........ | 2 | 3 | 5 |
| Aug. 13 | 6 | 7 | 5 | 18 | Sept. 8 | ........ | ........ | 1 | 1 |
| Aug. 14 | 8 | 9 | 9 | 26 | | | | | |
| Aug. 15 | 3 | 5 | 17 | 25 | Total.. | 153 | 201 | 262 | 762 |

### FIRST BROOD OF MOTHS, OR SUMMER MOTHS.

*Time of emergence* (fig. 7 and Table XV).—The records of emergence of the first brood of moths are from band-record material and should closely represent the actual time and rate of appearance of moths in the field. The larvæ used in these experiments were from three separate band records (see Table XV), and the curve of figure 7 represents the sum total of daily emergence from the combined sources. The first moth appeared July 26; a maximum of emergence occurred August 22, after which date only a few moths issued; the last moth of the brood emerged September 8.

From the point of view of mechanical control the time of emergence of moths of the second brood of the codling moth becomes of foremost importance, and this is one of the phases in the life history of the insect in which the literature on the codling moth is particularly deficient. This is mainly because of the difficult task of establishing accurate data, which at present involves carefully conducted band-record experiments. It is necessary that the bands be started in proper time and that the larvæ be collected at regular and preferably at short intervals (three days) in order that the records on the emergence of moths may become fully reliable.

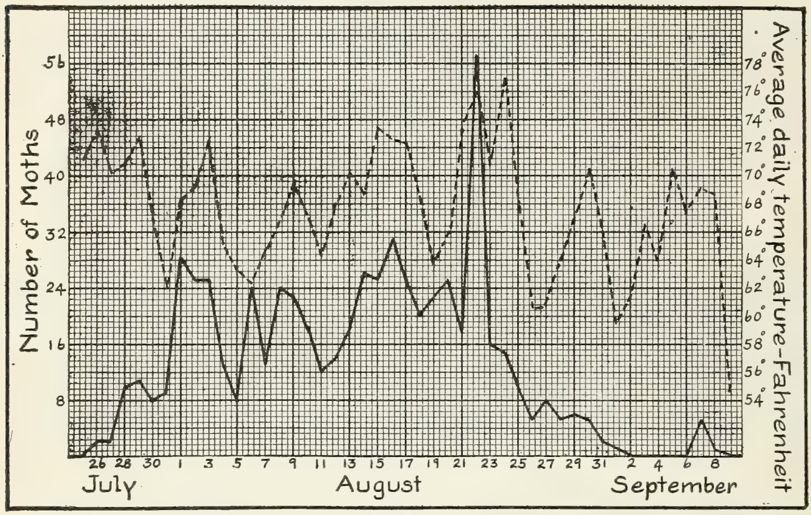


FIG. 7.—Emergence curve of summer brood of moths in 1910, at Douglas, Mich. (Original.)

*Time of oviposition.*—The so-called stock-jar experiments of Table XVI, including moths of the first brood, have been carried out under identically similar conditions as described on page 13 for the spring brood of moths. Egg deposition commenced from two to three days after the time of emergence of the moths, and extended on an average over a period of one week. In one instance eggs were laid 18 days after the date of emergence of the moths.

TABLE XVI.—*Egg deposition of the summer brood of moths in rearing cages, Douglas, Mich., 1910.*

| No. of experiment. | Number of moths. | Date of— | | | Number of days— | | |
|---|---|---|---|---|---|---|---|
| | | Emergence of moths. | First oviposition. | Last oviposition. | Before first oviposition. | Of egg deposition. | From date of emergence to last oviposition. |
| 1 | 10 | Aug. 11 | Aug. 14 | Aug. 19 | 3 | 6 | 8 |
| 2 | 10 | Aug. 12 | Aug. 16 | Aug. 24 | 4 | 9 | 12 |
| 3 | 26 | Aug. 14 | ...do.... | Sept. 1 | 2 | 17 | 18 |
| 4 | 20 | Aug. 16 | Aug. 19 | Aug. 25 | 3 | 7 | 9 |
| 5 | 30 | Aug. 17 | ...do.... | ...do.... | 2 | 7 | 8 |
| 6 | 20 | Aug. 18 | Aug. 20 | Aug. 26 | 2 | 7 | 8 |
| 7 | 27 | Aug. 19 | Aug. 22 | Aug. 25 | 3 | 4 | 6 |
| 8 | 30 | Aug. 20 | ...do.... | Aug. 29 | 2 | 8 | 9 |
| 9 | 10 | Aug. 21 | Aug. 25 | Aug. 28 | 4 | 4 | 7 |
| 10 | 53 | Aug. 22 | Aug. 24 | Aug. 26 | 2 | 3 | 4 |
| 11 | 11 | Aug. 23 | Aug. 25 | Aug. 25 | 2 | 1 | 2 |
| Average | | | | | 2.6 | 6.6 | 8.2 |
| Maximum | | | | | 4 | 17 | 18 |
| Minimum | | | | | 2 | 1 | 2 |

*Egg deposition by individual moths.*—Observations were taken on the egg deposition of six individual moths in captivity as given in Tables XVII, XVIII, and XIX. In most of these experiments pairs of male and female moths were used, which were removed from the stock jars before any oviposition had taken place.

TABLE XVII.—*Egg deposition by individual moths of the summer brood, Douglas, Mich., 1910.*

| Date of egg deposition. | Number of individual moths. | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| | Date of emergence. | | | | | |
| | July 28. | Aug. 4. | Aug. 10. | Aug. 11. | Aug. 14. | Aug. 15. |
| Aug. 5 | 27 | | | | | |
| Aug. 7 | 6 | | | | | |
| Aug. 8 | 11 | 36 | | | | |
| Aug. 9 | 6 | 13 | | | | |
| Aug. 10 | 8 | 22 | | | | |
| Aug. 11 | 10 | | | | | |
| Aug. 12 | 17 | | | | | |
| Aug. 13 | 6 | | | | | |
| Aug. 15 | | | 5 | | | |
| Aug. 16 | | | 4 | | | |
| Aug. 17 | | | 7 | 1 | | 1 |
| Aug. 18 | | | 2 | 1 | | 1 |
| Aug. 19 | | | | 3 | 3 | |
| Aug. 20 | | | | 2 | 6 | |
| Aug. 21 | | | | 4 | 8 | 2 |
| Aug. 22 | | | | | | 3 |
| | Date of death of moths. | | | | | |
| | Aug. 14 | Aug. 12. | Aug. 25. | Aug. 23. | Aug. 24. | Aug. 26. |

The moths of experiment No. 2 were found mating at 10.30 a. m., August 6, or two days previous to the first egg deposition. On an average the first eggs were laid five days after the emergence of the moths and for an average period of five days; the maximum number of eggs per female was 91; the average number of eggs per female, 35.8. These figures are lower than those from similar but later experiments in 1911.

TABLE XVIII.—*Egg deposition by individual moths of the summer brood; summary of Table XVII.*

| Observations. | Number of individual months. | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Total eggs per female | 91 | 71 | 18 | 11 | 17 | 7 |
| Days before egg deposition | 8 | 4 | 5 | 6 | 5 | 2 |
| Days duration of egg deposition | 9 | 3 | 4 | 5 | 3 | 6 |
| Days alive after egg deposition | 1 | 2 | 7 | 2 | 3 | 4 |
| Days moths lived | 17 | 8 | 15 | 12 | 10 | 11 |

TABLE XIX.—*Egg deposition by individual moths of the summer brood; summary of Table XVII.*

| Observations. | Average. | Maximum. | Minimum. |
|---|---|---|---|
| Eggs per female | 35.8 | 91 | 7 |
| Eggs per day per female | 7.16 | 36 | 1 |
| Days before egg deposition per female | 5 | 8 | 2 |
| Days of egg deposition per female | 5 | 9 | 3 |
| Days moths lived after egg deposition | 3.18 | 7 | 1 |
| Days moths lived | 12.1 | 17 | 8 |

The moths were confined in common jelly glasses with perforated tin covers. A fresh pear leaf was inserted for egg deposition, and food was given in the form of dilute sugar and honey solution placed on a small piece of sponge. Most of the eggs were laid on the leaves, though a few were invariably also found on the glass.

Judging from the records of emergence of moths and their habits as observed above, it becomes evident that the earliest eggs from this brood were laid about August 3. The height of the egg deposition period should have been September 1, and the close of the period September 15.

*Length of life of moths.*—A record on the length of the life of the summer moths in the so-called stock jars was taken on 445 individuals (Tables XX and XXI). These moths were kept under similar conditions to those of the spring brood.

TABLE XX.—*Length of life of moths of the first brood, in confinement, Douglas, Mich., 1910.*

| Number. | Length of life. | Number. | Length of life. | Number. | Length of life. | Number. | Length of life. |
|---|---|---|---|---|---|---|---|
| | *Days.* | | *Days.* | | *Days.* | | *Days.* |
| 5 | 2 | 70 | 7 | 39 | 12 | 9 | 17 |
| 15 | 3 | 49 | 8 | 27 | 13 | 4 | 18 |
| 14 | 4 | 56 | 9 | 18 | 14 | 2 | 19 |
| 34 | 5 | 27 | 10 | 5 | 15 | 2 | 20 |
| 41 | 6 | 23 | 11 | 4 | 16 | 1 | 24 |

Total number of moths, 445.

TABLE XXI.—*Length of life of moths of the first brood in confinement, Douglas, Mich., 1910; summary of Table XX.*

| Observations. | Length of life. |
|---|---|
| | *Days.* |
| Average | 8.93 |
| Maximum | 24 |
| Minimum | 2 |

The results of observations on the length of life for the two broods of moths are practically the same (compare Tables XI and XXI).

### LIFE CYCLE OF THE FIRST GENERATION.

In the preceding pages the separate stages of the first generation have been considered at length, and the length of time of the development has been determined by a number of experiments for each stage. The final figures from these records thus represent the average life cycle of the codling moth of the first generation.

| | Days. |
|---|---|
| Incubation period of eggs | 6 |
| Length of feeding of larvæ | 25 |
| Time of larvæ in cocoons | 7 |
| Length of pupal stage | 13. 6 |
| Total | 51. 6 |

To test the accuracy of the various experiments for the separate stages an additional experiment was undertaken in which a number of individual insects were carried through from the time of hatching to the emergence of the moths.

TABLE XXII.—*Length of life cycle of the first generation, as determined by rearing in 1910 at Douglas, Mich.*

| No. of individual. | Date of— | | | | | Days— | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Egg deposition. | Hatching. | Leaving the fruit. | Pupation. | Emergence. | Incubation. | Feeding of— | | In cocoon as larva. | Pupal stage. | Total life cycle. |
| | | | | | | | Transforming larvæ. | Wintering larvæ. | | | |
| 1 | June 25 | July 2 | July 26 | July 31 | Aug. 15 | 7 | 24 | | 5 | 15 | 51 |
| 2 | do. | do. | July 28 | | | 7 | | 26 | | | |
| 3 | do. | do. | July 29 | Aug. 2 | Aug. 18 | 7 | 27 | | 4 | 16 | 54 |
| 4 | do. | do. | July 30 | | | 7 | | 28 | | | |
| 5 | do. | do. | do. | Aug. 8 | Aug. 23 | 7 | 28 | | 9 | 15 | 59 |
| 6 | do. | do. | July 31 | Aug. 9 | do. | 7 | 29 | | 9 | 14 | 59 |
| 7 | do. | do. | Aug. 1 | | | 7 | | 30 | | | |
| 8 | June 28 | July 4 | July 24 | July 29 | Aug. 13 | 6 | 20 | | 5 | 15 | 46 |
| 9 | do. | do. | do. | do. | do. | 6 | 20 | | 5 | 15 | 46 |
| 10 | do. | do. | July 26 | July 31 | Aug. 16 | 6 | 22 | | 5 | 16 | 49 |
| 11 | do. | do. | July 27 | Aug. 2 | Aug. 18 | 6 | 23 | | 6 | 16 | 51 |
| 12 | do. | do. | do. | do. | Aug. 20 | 6 | 23 | | 6 | 18 | 53 |
| 13 | do. | do. | do. | do. | Aug. 15 | 6 | 23 | | 6 | 13 | 48 |
| 14 | do. | do. | July 28 | | | 6 | | 24 | | | |
| 15 | do. | do. | July 30 | | | 6 | | 26 | | | |
| 16 | June 30 | do. | July 23 | July 27 | Aug. 12 | 6 | 17 | | 4 | 16 | 43 |
| 17 | do. | July 6 | July 29 | | | 6 | | 23 | | | |
| 18 | do. | do. | July 30 | | | 6 | | 24 | | | |
| 19 | do. | do. | Aug. 1 | | | 6 | | 26 | | | |
| 20 | do. | do. | Aug. 2 | Aug. 6 | Aug. 20 | 6 | 27 | | 4 | 14 | 51 |
| 21 | do. | do. | do. | Aug. 12 | Aug. 24 | 6 | 27 | | 10 | 12 | 55 |
| 22 | do. | do. | Aug. 3 | | | 6 | | 28 | | | |
| 23 | do. | do. | Aug. 4 | | | 6 | | 29 | | | |
| 24 | do. | do. | Aug. 6 | Aug. 17 | Sept. 1 | 6 | 31 | | 11 | 15 | 63 |
| 25 | do. | do. | do. | | | 6 | | 31 | | | |
| 26 | July 1 | July 8 | July 25 | | | 7 | | 17 | | | |
| 27 | do. | do. | July 28 | | | 7 | | 20 | | | |
| 28 | do. | do. | Aug. 2 | Aug. 4 | Aug. 18 | 7 | 25 | | 2 | 14 | 48 |
| 29 | do. | do. | do. | do. | Aug. 19 | 7 | 25 | | 2 | 15 | 49 |
| 30 | do. | do. | do. | Aug. 9 | Aug. 23 | 7 | 25 | | 7 | 14 | 53 |
| 31 | do. | do. | Aug. 3 | | | 7 | | 26 | | | |
| 32 | do. | do. | Aug. 4 | | | 7 | | 27 | | | |
| 33 | do. | do. | Aug. 5 | | | 7 | | 28 | | | |
| 34 | do. | do. | Aug. 6 | | | 7 | | 29 | | | |
| 35 | do. | do. | Aug. 9 | | | 7 | | 32 | | | |
| 36 | do. | do. | Aug. 13 | | | 7 | | 36 | | | |
| 37 | do. | do. | Aug. 22 | | | 7 | | 45 | | | |
| 38 | July 5 | July 11 | Aug. 3 | | | 6 | | 23 | | | |
| 39 | do. | do. | Aug. 4 | Aug. 12 | Aug. 25 | 6 | 24 | | 8 | 13 | 51 |
| 40 | do. | do. | Aug. 6 | Aug. 13 | Aug. 26 | 6 | 26 | | 7 | 13 | 52 |
| 41 | do. | do. | Aug. 8 | do. | Aug. 25 | 6 | 28 | | 5 | 12 | 51 |
| 42 | do. | do. | Aug. 9 | do. | | 6 | | 29 | 4 | | |
| 43 | do. | do. | Aug. 13 | | | 6 | | 33 | | | |
| 44 | July 7 | July 13 | Aug. 12 | | | 6 | | 30 | | | |
| 45 | do. | do. | do. | | | 6 | | 30 | | | |
| 46 | do. | do. | Aug. 13 | | | 6 | | 31 | | | |
| 47 | do. | do. | do. | | | 6 | | 31 | | | |
| 48 | do. | do. | do. | | | 6 | | 31 | | | |
| 49 | do. | do. | Aug. 15 | | | 6 | | 33 | | | |
| 50 | do. | do. | Aug. 17 | | | 6 | | 35 | | | |
| 51 | do. | do. | do. | | | 6 | | 35 | | | |

TABLE XXIII.—*Life cycle of the first generation; summary of Table XXII.*

| | Incubation. | Feeding of— | | In cocoon as larva. | Pupal stage. | Total life cycle. |
|---|---|---|---|---|---|---|
| | | Transforming larvæ. | Wintering larvæ. | | | |
| | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* |
| Average | 6.37 | 24.7 | 28.9 | 6.0 | 14.5 | 51.5 |
| Maximum | 7 | 31 | 45 | 11 | 18 | 63 |
| Minimum | 6 | 17 | | 2 | 12 | 43 |

The results of these experiments are given in Tables XXII and XXIII. Although limited in number the results of these experiments agree very closely with those of the previous experiments for the separate stages, namely, the life-cycle experiments averaged 51.5 days, and the final average for the various experiments on separate stages averaged 51.6 days.

The wintering larvæ of the first brood, which complete their life cycle the following spring, have not been included in the consideration of the life cycle of the first generation.

### THE SECOND GENERATION.

#### SECOND BROOD OF EGGS.

*Length of incubation.*—On an average the second brood of eggs (Tables XXIV and XXV) required 7.5 days for hatching, which is one day longer than was found necessary for those of the first brood. The maximum length of time for incubation was 11 days, the minimum 6 days. The red ring became first visible from three to four days after egg deposition and the black spot two days before hatching.

TABLE XXIV.—*Length of incubation of the second brood of eggs laid in rearing cages, Douglas, Mich., 1910.*

| No. of observation. | Date of— | | | | Duration of— | | |
|---|---|---|---|---|---|---|---|
| | Egg deposition. | Appearance of red ring. | Appearance of black spot. | Hatching. | Red ring. | Black spot. | Incubation. |
| | | | | | *Days.* | *Days.* | *Days.* |
| 1 | Aug. 2 | Aug. 5 | Aug. 10 | Aug. 12 | 3 | 8 | 10 |
| 2 | ...do.... | ...do.... | ...do.... | Aug. 13 | 3 | 8 | 11 |
| 3 | Aug. 3 | ...do.... | Aug. 9 | Aug. 11 | 2 | 6 | 8 |
| 4 | Aug. 4 | Aug. 10 | Aug. 11 | Aug. 13 | 6 | 7 | 9 |
| 5 | ...do.... | ...do.... | ...do.... | Aug. 14 | 6 | 7 | 10 |
| 6 | Aug. 6 | .......... | .......... | ...do.... | ........ | ........ | 8 |
| 7 | Aug. 7 | Aug. 12 | Aug. 14 | Aug. 15 | 5 | 7 | 8 |
| 8 | ...do.... | ...do.... | ...do.... | Aug. 16 | 5 | 7 | 9 |
| 9 | Aug. 8 | Aug. 13 | ...do.... | Aug. 15 | 5 | 6 | 7 |
| 10 | ...do.... | ...do.... | ...do.... | Aug. 16 | 5 | 6 | 8 |
| 11 | Aug. 9 | Aug. 12 | ...do.... | ...do.... | 3 | 5 | 7 |
| 12 | ...do.... | ...do.... | ...do.... | Aug. 17 | 3 | 5 | 8 |
| 13 | Aug. 10 | Aug. 14 | Aug. 16 | ...do.... | 4 | 6 | 7 |
| 14 | Aug. 11 | ...do.... | ...do.... | ...do.... | 3 | 5 | 6 |
| 15 | ...do.... | ...do.... | ...do.... | Aug. 18 | 3 | 5 | 7 |
| 16 | Aug. 12 | Aug. 15 | Aug. 17 | ...do.... | 3 | 5 | 6 |
| 17 | ...do.... | ...do.... | ...do.... | Aug. 19 | 3 | 5 | 7 |
| 18 | Aug. 13 | Aug. 16 | Aug. 18 | ...do.... | 3 | 5 | 6 |
| 19 | ...do.... | ...do.... | ...do.... | Aug. 20 | 3 | 5 | 7 |
| 20 | Aug. 14 | ...do.... | ...do.... | ...do.... | 2 | 4 | 6 |
| 21 | Aug. 15 | Aug. 17 | Aug. 19 | Aug. 21 | 2 | 4 | 6 |
| 22 | ...do.... | ...do.... | ...do.... | Aug. 22 | 2 | 4 | 7 |
| 23 | Aug. 16 | Aug. 18 | Aug. 21 | ...do.... | 2 | 5 | 6 |
| 24 | ...do.... | ...do.... | ...do.... | Aug. 23 | 2 | 5 | 7 |
| 25 | Aug. 17 | Aug. 19 | ...do.... | ...do.... | 2 | 4 | 6 |
| 26 | ...do.... | ...do.... | ...do.... | Aug. 24 | 2 | 4 | 7 |
| 27 | Aug. 18 | Aug. 21 | Aug. 23 | ...do.... | 3 | 5 | 6 |
| 28 | Aug. 19 | Aug. 22 | Aug. 24 | Aug. 25 | 3 | 5 | 6 |
| 29 | Aug. 20 | Aug. 23 | Aug. 25 | Aug. 27 | 3 | 5 | 7 |
| 30 | Aug. 21 | ...do.... | ...do.... | ...do.... | 2 | 4 | 6 |
| 31 | ...do.... | ...do.... | ...do.... | Aug. 28 | 2 | 4 | 7 |
| 32 | Aug. 22 | Aug. 25 | Aug. 27 | ...do.... | 3 | 5 | 6 |
| 33 | ...do.... | ...do.... | ...do.... | Aug. 29 | 3 | 5 | 7 |
| 34 | Aug. 23 | Aug. 26 | Aug. 28 | ...do.... | 3 | 5 | 6 |
| 35 | ...do.... | ...do.... | ...do.... | Aug. 30 | 3 | 5 | 7 |
| 36 | Aug. 24 | Aug. 27 | Aug. 29 | ...do.... | 3 | 5 | 6 |
| 37 | ...do.... | ...do.... | ...do.... | Aug. 31 | 3 | 5 | 7 |
| 38 | Aug. 25 | Aug. 29 | Aug. 31 | Sept. 2 | 4 | 6 | 8 |
| 39 | ...do.... | ...do.... | ...do.... | Sept. 3 | 4 | 6 | 9 |
| 40 | Aug. 26 | Aug. 30 | Sept. 1 | ...do.... | 4 | 6 | 8 |
| 41 | ...do.... | ...do.... | ...do.... | Sept. 4 | 4 | 6 | 9 |
| 42 | Aug. 28 | Sept. 2 | Sept. 4 | Sept. 5 | 5 | 7 | 8 |
| 43 | ...do.... | ...do.... | ...do.... | Sept. 6 | 5 | 7 | 9 |
| 44 | ...do.... | ...do.... | ...do.... | Sept. 7 | 5 | 7 | 10 |
| 45 | Aug. 29 | Sept. 3 | Sept. 5 | Sept. 6 | 5 | 7 | 8 |
| 46 | ...do.... | ...do.... | ...do.... | Sept. 7 | 5 | 7 | 9 |
| Average | | | | | 3.4 | 5.5 | 7.4 |
| Maximum | | | | | 6 | 8 | 11 |
| Minimum | | | | | 2 | 4 | 6 |

TABLE XXV.—*Incubation period of eggs of the second brood in rearing cages, Douglas, Mich., 1910; summary of Table XXIV.*

| Appearance of red ring. | | Appearance of black spot. | | Total incubation period. | |
|---|---|---|---|---|---|
| Number of days. | Number of observations. | Number of days. | Number of observations. | Number of days. | Number of observations. |
| 2 | 10 | 4 | 7 | 6 | 13 |
| 3 | 19 | 5 | 19 | 7 | 14 |
| 4 | 5 | 6 | 8 | 8 | 9 |
| 5 | 9 | 7 | 9 | 9 | 6 |
| 6 | 2 | 8 | 2 | 10 | 3 |
| .......... | .......... | .......... | .......... | 11 | 1 |

SECOND BROOD OF LARVÆ.

*Time of hatching.*—The time of hatching of second-brood larvæ under orchard conditions has been determined by methods described on page 14 for the first brood. A maximum abundance of newly hatched larvæ occurred about September 10. The earliest larva of the brood hatched August 12. In the cages several late-deposited eggs failed to hatch, and it is possible that eggs in the field at this time would likewise remain undeveloped.

TABLE XXVI.—*Length of feeding of second-brood larvæ, Douglas, Mich., 1910.*

| No. of observation. | Date of— | | Days of feeding. | No. of observation. | Date of— | | Days of feeding. | No. of observation. | Date of— | | Days of feeding. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hatching. | Leaving the fruit. | | | Hatching. | Leaving the fruit. | | | Hatching. | Leaving the fruit. | |
| 1 | Aug. 15 | Sept. 12 | 28 | 28 | Aug. 19 | Oct. 1 | 43 | 55 | Aug. 24 | Oct. 1 | 38 |
| 2 | ...do..... | Sept. 13 | 29 | 29 | Aug. 20 | Sept. 24 | 35 | 56 | ...do..... | ...do..... | 38 |
| 3 | ...do..... | ...do..... | 29 | 30 | ...do..... | ...do..... | 35 | 57 | ...do..... | Oct. 2 | 39 |
| 4 | ...do..... | ...do..... | 29 | 31 | Aug. 21 | Sept. 15 | 25 | 58 | ...do..... | ...do..... | 39 |
| 5 | ...do..... | Sept. 15 | 31 | 32 | ...do..... | Sept. 20 | 30 | 59 | Aug. 25 | Sept. 15 | 21 |
| 6 | Aug. 17 | Sept. 20 | 34 | 33 | ...do..... | Sept. 21 | 31 | 60 | ...do..... | Sept. 27 | 33 |
| 7 | ...do..... | Sept. 24 | 38 | 34 | ...do..... | Sept. 22 | 32 | 61 | ...do..... | Oct. 1 | 37 |
| 8 | ...do..... | ...do..... | 38 | 35 | ...do..... | Sept. 23 | 33 | 62 | Aug. 26 | Oct. 2 | 37 |
| 9 | ...do..... | Oct. 1 | 45 | 36 | ...do..... | Sept. 24 | 34 | 63 | ...do..... | Oct. 3 | 38 |
| 10 | Aug. 18 | Sept. 23 | 36 | 37 | Aug. 22 | Sept. 12 | 21 | 64 | ...do..... | ...do..... | 38 |
| 11 | ...do..... | Sept. 24 | 37 | 38 | ...do..... | ...do..... | 21 | 65 | ...do..... | Oct. 7 | 42 |
| 12 | ...do..... | ...do..... | 37 | 39 | ...do..... | Sept. 23 | 32 | 66 | Aug. 28 | Sept. 24 | 27 |
| 13 | ...do..... | Sept. 28 | 41 | 40 | ...do..... | ...do..... | 32 | 67 | ...do..... | Oct. 3 | 36 |
| 14 | ...do..... | Oct. 1 | 44 | 41 | ...do..... | ...do..... | 32 | 68 | ...do..... | ...do..... | 36 |
| 15 | Aug. 19 | Sept. 12 | 24 | 42 | ...do..... | Sept. 26 | 35 | 69 | ...do..... | ...do..... | 36 |
| 16 | ...do..... | ...do..... | 24 | 43 | Aug. 23 | Sept. 23 | 31 | 70 | ...do..... | Oct. 4 | 37 |
| 17 | ...do..... | Sept. 15 | 27 | 44 | ...do..... | ...do..... | 31 | 71 | ...do..... | ...do..... | 37 |
| 18 | ...do..... | ...do..... | 27 | 45 | ...do..... | Oct. 1 | 39 | 72 | ...do..... | Oct. 6 | 39 |
| 19 | ...do..... | Sept. 20 | 32 | 46 | ...do..... | ...do..... | 39 | 73 | ...do..... | ...do..... | 39 |
| 20 | ...do..... | ...do..... | 32 | 47 | ...do..... | Oct. 3 | 41 | 74 | Aug. 29 | Oct. 10 | 42 |
| 21 | ...do..... | ...do..... | 32 | 48 | Aug. 24 | Sept. 21 | 28 | 75 | Aug. 30 | Sept. 25 | 26 |
| 22 | ...do..... | Oct. 1 | 43 | 49 | ...do..... | Sept. 23 | 30 | 76 | ...do..... | Sept. 29 | 30 |
| 23 | ...do..... | ...do..... | 43 | 50 | ...do..... | ...do..... | 30 | 77 | Aug. 31 | Oct. 4 | 34 |
| 24 | ...do..... | ...do..... | 43 | 51 | ...do..... | Sept. 24 | 31 | 78 | ...do..... | Oct. 6 | 36 |
| 25 | ...do..... | ...do..... | 43 | 52 | ...do..... | Sept. 25 | 32 | 79 | ...do..... | ...do..... | 36 |
| 26 | ...do..... | ...do..... | 43 | 53 | ...do..... | ...do..... | 32 | 80 | Sept. 3 | Oct. 1 | 28 |
| 27 | ...do..... | ...do..... | 43 | 54 | ...do..... | ...do..... | 32 | 81 | Sept. 4 | Oct. 6 | 32 |
| Average | | | | | | | | | | | 34.2 |
| Maximum | | | | | | | | | | | 45 |
| Minimum | | | | | | | | | | | 21 |

TABLE XXVII.—*Feeding period of second-brood larvæ; summary of Table XXVI.*

| Number of observations. | Days of feeding. | Number of observations. | Days of feeding. | Number of observations. | Days of feeding. |
|---|---|---|---|---|---|
| 3 | 21 | 5 | 31 | 6 | 39 |
| 2 | 24 | 11 | 32 | 2 | 41 |
| 1 | 25 | 2 | 33 | 2 | 42 |
| 1 | 26 | 3 | 34 | 7 | 43 |
| 3 | 27 | 3 | 35 | 1 | 44 |
| 3 | 28 | 6 | 36 | 1 | 45 |
| 3 | 29 | 6 | 37 | | |
| 4 | 30 | 6 | 38 | 81 | 2,770 |

*Length of feeding period.*—In Table XXVI will be found the records on the feeding periods for 81 individual larvæ of the second brood. The average length of feeding for the total number of observations is 34.2 days, the maximum 45 days, and the minimum 21 days. As is to be expected these results are much higher than those for the first brood (compare with Table XXIII), since at this time of year a much lower degree of temperature prevails, and more feeding may be necessary for the hibernating larvæ. Figure 8 (p. 26) shows the jar used in the rearing of codling moth larvæ.

*Time of leaving the fruit.*—The Saugatuck band-record experiment of figure 10 shows that the earliest mature larvæ appeared under the bands August 30, and that larvæ were collected more or less abundantly throughout September and the early part of October. The almost total absence of larvæ during November was to a large extent due to the scarcity of fruit, and this condition materially limited the number of second-brood larvæ.

TABLE XXVIII.—*Band-record experiments, Saugatuck, Mich., 1910.*

| No. of record. | Date of collecting. | No. of larvæ. | No. of moths, 1910. | No. of parasites, 1910. | No. of moths, 1911. | No. of parasites, 1911. | Total number of dead larvæ. | No. of record. | Date of collecting. | No. of larvæ. | No. of moths, 1910. | No. of parasites, 1910. | No. of moths, 1911. | No. of parasites, 1911. | Total number of dead larvæ. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | July 13 | 6 | 5 | ..... | ..... | ..... | 1 | 21 | Sept. 12 | 13 | ..... | ..... | 11 | 1 | 1 |
| 2 | July 17 | 41 | 34 | ..... | ..... | ..... | 7 | 22 | Sept. 15 | 18 | ..... | ..... | 15 | 3 | 0 |
| 3 | July 20 | 28 | 10 | ..... | 1 | ..... | 17 | 23 | Sept. 18 | 19 | ..... | ..... | 9 | 3 | 7 |
| 4 | July 23 | 34 | 19 | 1 | 1 | ..... | 13 | 24 | Sept. 21 | [1] 26 | ..... | ..... | 6 | 2 | [1] 18 |
| 5 | July 26 | 54 | 26 | 2 | 5 | 1 | 20 | 25 | Sept. 24 | 16 | ..... | ..... | 11 | ..... | 5 |
| 6 | July 29 | 35 | 21 | 1 | 2 | 1 | 10 | 26 | Sept. 27 | 10 | ..... | ..... | 6 | 1 | 3 |
| 7 | Aug. 1 | 58 | 33 | 2 | 3 | ..... | 20 | 27 | Sept. 30 | 7 | ..... | ..... | 5 | 2 | 0 |
| 8 | Aug. 4 | 54 | 30 | 1 | 8 | 1 | 14 | 28 | Oct. 3 | 22 | ..... | ..... | 19 | ..... | 3 |
| 9 | Aug. 7 | 49 | 13 | 1 | 18 | ..... | 17 | 29 | Oct. 6 | 13 | ..... | ..... | 9 | 1 | 3 |
| 10 | Aug. 10 | 27 | 8 | ..... | 18 | ..... | 1 | 30 | Oct. 9 | 3 | ..... | ..... | 1 | 2 | 0 |
| 11 | Aug. 13 | 35 | 2 | ..... | 25 | ..... | 8 | 31 | Oct. 12 | 9 | ..... | ..... | 9 | ..... | 0 |
| 12 | Aug. 16 | 32 | ..... | ..... | 24 | ..... | 8 | 32 | Oct. 15 | 11 | ..... | ..... | 5 | ..... | 6 |
| 13 | Aug. 19 | 23 | ..... | ..... | 17 | ..... | 6 | 33 | Oct. 18 | 8 | ..... | ..... | 5 | ..... | 3 |
| 14 | Aug. 22 | 35 | ..... | ..... | 28 | ..... | 7 | 34 | Oct. 21 | 5 | ..... | ..... | 3 | 1 | 1 |
| 15 | Aug. 25 | 23 | ..... | ..... | 9 | 1 | 13 | 35 | Oct. 24 | 3 | ..... | ..... | 2 | ..... | 1 |
| 16 | Aug. 28 | 14 | ..... | ..... | 9 | 2 | 3 | 36 | Oct. 28 | 2 | ..... | ..... | ..... | ..... | 2 |
| 17 | Sept. 1 | 21 | ..... | ..... | 11 | 1 | 9 | 37 | Oct. 30 | 0 | ..... | ..... | ..... | ..... | 0 |
| 18 | Sept. 3 | 8 | ..... | ..... | 6 | 2 | ..... | 38 | Nov. 2 | 2 | ..... | ..... | ..... | ..... | 1 |
| 19 | Sept. 6 | 7 | ..... | ..... | 4 | ..... | 3 | | | | | | | | |
| 20 | Sept. 9 | 17 | ..... | ..... | 7 | 4 | 6 | | Total | 788 | 201 | 8 | 313 | 29 | 237 |

[1] 12 larvæ escaped.

## BAND RECORDS OF 1910.

The band-record experiments form a very important part in the study of the life history of the codling moth, and constitute at present the only safe test of the development of the insect under natural conditions. When carefully carried out these experiments furnish indispensable data on the relative abundance of the first and second broods of larvæ, time of emergence of moths, parasitism, hibernation, etc. (see Table XXXI), and yield in addition an abundance of material for laboratory rearing experiments.

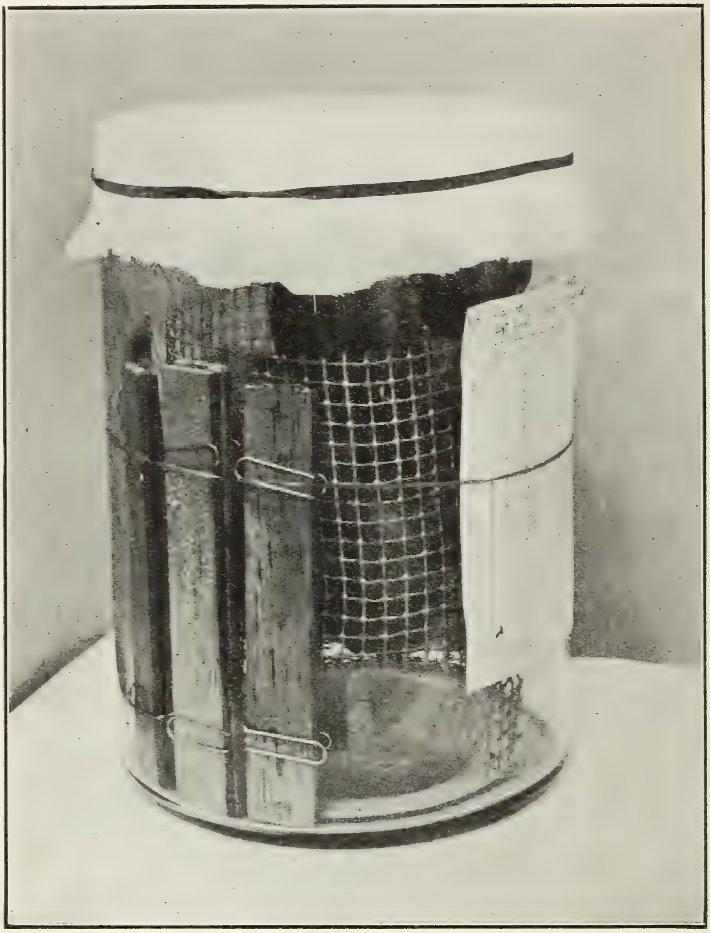


Fig. 8.—Cage used in determining feeding period of codling-moth larvæ. (Original.)

TABLE XXIX.—*Lake Shore band-record experiments, Douglas, Mich., 1910.*

| No. of record. | Date of collecting. | No. of larvæ. | No. of moths, 1910. | No. of parasites, 1910. | No. of moths, 1911. | No. of parasites, 1911. | Total number of dead larvæ. | No. of record. | Date of collecting. | No. of larvæ. | No. of moths, 1910. | No. of parasites, 1910. | No. of moths, 1911. | No. of parasites, 1911. | Total number of dead larvæ. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | July 12 | 18 | 17 | 1 | ..... | ..... | .... | 23 | Sept. 16 | 18 | ..... | ..... | 8 | 1 | 9 |
| 2 | July 15 | 30 | 22 | ..... | ..... | ..... | 8 | 24 | Sept. 19 | 15 | ..... | ..... | 8 | 3 | 4 |
| 3 | July 18 | 40 | 28 | 2 | ..... | ..... | 10 | 25 | Sept. 22 | 8 | ..... | ..... | 3 | ..... | 5 |
| 4 | July 21 | 31 | 17 | 4 | ..... | ..... | 10 | 26 | Sept. 25 | 14 | ..... | ..... | 2 | 3 | 9 |
| 5 | July 24 | 45 | 27 | 4 | ..... | ..... | 14 | 27 | Sept. 28 | 7 | ..... | ..... | 2 | ..... | 5 |
| 6 | July 27 | 75 | 45 | 7 | 4 | 1 | 18 | 28 | Oct. 1 | 9 | ..... | ..... | 6 | 1 | 2 |
| 7 | July 30 | 51 | 35 | 2 | 8 | 1 | 5 | 29 | Oct. 4 | 1 | ..... | ..... | 1 | ..... | 0 |
| 8 | Aug. 2 | 42 | 28 | 5 | 7 | ..... | 2 | 30 | Oct. 7 | 5 | ..... | ..... | 4 | 1 | 0 |
| 9 | Aug. 5 | 59 | 25 | 4 | 22 | 1 | 7 | 31 | Oct. 10 | 0 | ..... | ..... | ..... | ..... | 0 |
| 10 | Aug. 8 | 59 | 8 | 1 | 20 | 5 | 25 | 32 | Oct. 13 | 3 | ..... | ..... | 1 | ..... | 2 |
| 11 | Aug. 11 | 59 | 9 | ..... | 29 | 4 | 17 | 33 | Oct. 16 | 1 | ..... | ..... | ..... | ..... | 1 |
| 12 | Aug. 14 | 66 | 1 | ..... | 41 | 4 | 20 | 34 | Oct. 19 | 4 | ..... | ..... | ..... | ..... | 4 |
| 13 | Aug. 17 | 69 | ..... | ..... | 46 | 2 | 21 | 35 | Oct. 22 | ..... | ..... | ..... | ..... | ..... | 0 |
| 14 | Aug. 20 | 50 | ..... | ..... | 37 | 1 | 12 | 36 | Oct. 25 | ..... | ..... | ..... | ..... | ..... | 0 |
| 15 | Aug. 23 | 42 | ..... | ..... | 36 | 1 | 5 | 37 | Oct. 29 | 2 | ..... | ..... | ..... | ..... | 2 |
| 16 | Aug. 25 | 40 | ..... | ..... | 23 | 2 | 15 | 38 | Oct. 31 | ..... | ..... | ..... | ..... | ..... | 0 |
| 17 | Aug. 29 | 22 | ..... | ..... | 11 | ..... | 11 | 39 | Nov. 3 | 1 | ..... | ..... | ..... | ..... | 1 |
| 18 | Sept. 1 | 27 | ..... | ..... | 16 | 3 | 8 | 40 | Nov. 6 | ..... | ..... | ..... | ..... | ..... | 0 |
| 19 | Sept. 4 | 24 | ..... | ..... | 15 | 3 | 6 | 41 | Nov. 9 | 2 | ..... | ..... | ..... | ..... | 2 |
| 20 | Sept. 7 | 11 | ..... | ..... | 9 | 1 | 1 | | | | | | | | |
| 21 | Sept. 10 | 16 | ..... | ..... | 9 | 3 | 4 | | Total. | 985 | 262 | 30 | 377 | 45 | 271 |
| 22 | Sept. 13 | 19 | ..... | ..... | 9 | 4 | 6 | | | | | | | | |

In 1910, band-record experiments were placed in three separate orchards, located several miles apart, for the purpose of establishing better average results and determining as far as possible the extent of existing variation in the time of development of the codling moth in the selected localities. These were chosen in regard to their relative proximity to Lake Michigan, one near the lake, one 2 miles east, and the other 7 miles east of the lake. The influence of the lake upon the temperature over the fruit belt of the western part of Michigan is well known by the local fruit growers and horticulturists and is strikingly shown by the difference in the period of blossoming of apples. This period is much earlier in orchards situated inland and later in orchards near the lake. It should therefore be expected that the codling moth is influenced in its development to a similar extent.

TABLE XXX.—*Band-record experiment at New Richmond, Mich., in 1910; larvæ collected by Mr. Herman Schultz.*

| No. of record. | Date of collecting. | No. of larvæ. | No. of moths, 1910. | No. of parasites, 1910. | No. of moths, 1911. | No. of parasites, 1911. | Total number of dead larvæ. | No. of record. | Date of collecting. | No. of larvæ. | No. of moths, 1910. | No. of parasites, 1910. | No. of moths, 1911. | No. of parasites, 1911. | Total number of dead larvæ. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | July 11 | 29 | 12 | 3 | ..... | ..... | 14 | 16 | Aug. 25 | 2 | ..... | ..... | 1 | ..... | 1 |
| 2 | July 14 | 55 | 27 | 2 | ..... | ..... | 26 | 17 | Aug. 28 | 8 | ..... | ..... | 6 | 1 | 1 |
| 3 | July 17 | 69 | 20 | 7 | 2 | ..... | 40 | 18 | Aug. 31 | 1 | ..... | ..... | 0 | 1 | 0 |
| 4 | July 20 | 57 | 24 | 4 | 11 | ..... | 18 | 19 | Sept. 3 | 9 | ..... | ..... | 6 | 1 | 2 |
| 5 | July 23 | 50 | 21 | 3 | 6 | ..... | 20 | 20 | Sept. 6 | 7 | ..... | ..... | 3 | ..... | 4 |
| 6 | July 26 | 50 | 17 | 8 | 6 | ..... | 19 | 21 | Sept. 9 | 7 | ..... | ..... | 4 | 1 | 2 |
| 7 | July 29 | 33 | 9 | 4 | 4 | ..... | 16 | 22 | Sept. 12 | 10 | ..... | ..... | 5 | ..... | 5 |
| 8 | Aug. 1 | 38 | 17 | 1 | 11 | 1 | 8 | 23 | Sept. 15 | [1] 5 | ..... | ..... | 1 | ..... | 0 |
| 9 | Aug. 4 | 22 | 3 | ..... | 11 | ..... | 8 | 24 | Sept. 18 | 10 | ..... | ..... | 3 | 1 | 6 |
| 10 | Aug. 7 | 15 | 2 | ..... | 10 | 1 | 2 | 25 | Sept. 21 | 6 | ..... | ..... | 2 | 2 | 2 |
| 11 | Aug. 10 | 15 | 1 | ..... | 11 | ..... | 3 | 26 | Sept. 24 | 3 | ..... | ..... | 2 | ..... | 1 |
| 12 | Aug. 13 | 15 | ..... | ..... | 11 | ..... | 4 | 27 | Sept. 27 | 5 | ..... | ..... | 3 | 1 | 1 |
| 13 | Aug. 16 | 7 | ..... | ..... | 5 | ..... | 2 | 28 | Sept. 30 | 1 | ..... | ..... | 0 | ..... | 1 |
| 14 | Aug. 19 | 5 | ..... | ..... | 4 | ..... | 1 | | | | | | | | |
| 15 | Aug. 22 | 9 | ..... | ..... | 9 | ..... | 0 | | | 543 | 153 | 32 | 137 | 10 | 207 |

[1] 4 larvæ escaped.

The three band records have been referred to as the Lake Shore experiments located near the shore of the lake southwest of Douglas; the Saugatuck experiments, 2 miles from the lake and northeast of Saugatuck, and the New Richmond experiments, near the village of the same name, 7 miles from the lake. Of these the Saugatuck experiments represented closely the locality of the field station and the results from these last band records have been used to supplement the laboratory rearing experiments.[1] Practically all of the apple trees used in these experiments were old and badly neglected, and none of the trees had for some time been sprayed with a poison spray, so that the codling moth had for years developed normally and unchecked in the above orchards.

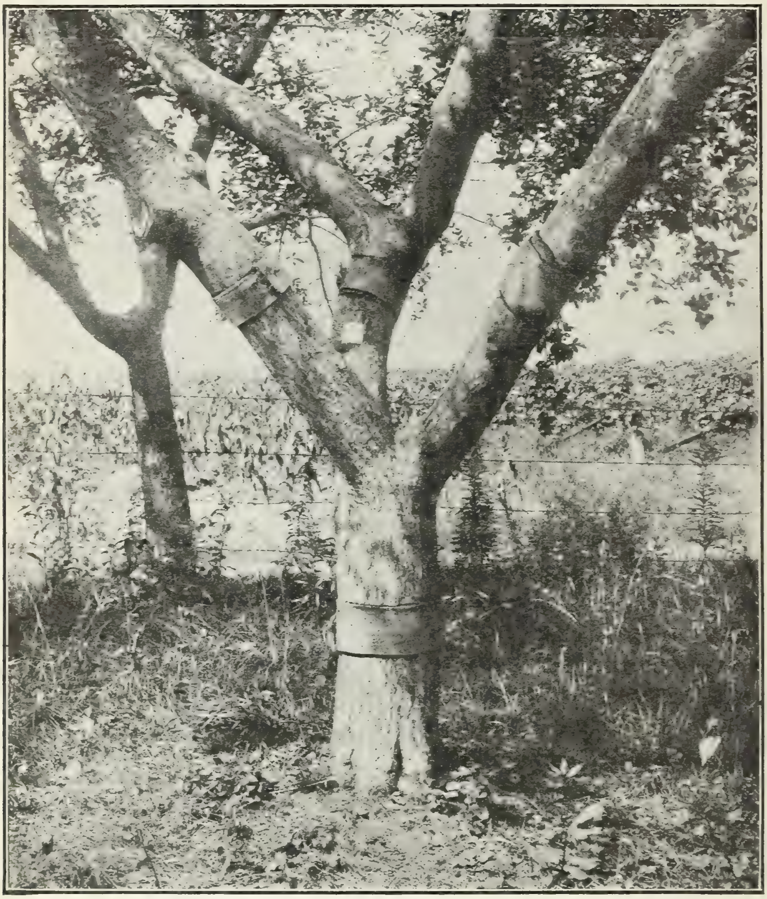


FIG. 9.—Burlap bands on an apple tree, to catch codling-moth larvæ. (Original.)

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[1] During 1909 and 1911 the band-record experiments, which in 1910 were interrupted on account of the absence of fruit during that season, were carried out in the orchard on the grounds of the station.

Whenever possible, winter varieties of apples have been used for the band records to test the extent of infestation of the second-brood larvæ. This was not entirely possible in case of the Lake Shore and the New Richmond experiments because of the great scarcity of fruit during 1910, so that in these localities summer and fall varieties were used, in addition to winter varieties. The apple trees of the Saugatuck band experiments consisted of the following varieties: Three Baldwin trees, one Greening tree, two Golden Russet trees, and one crabapple tree. Through the courtesy of Mr. Herman Schultz, of East Saugatuck, Mich., five of these trees were placed free of charge at the disposal of the station.

The apple trees were prepared for the band experiment in the usual way. The loose and rough bark was scraped off from the trunk and main branches. Cracks and crevices and decayed hollows in the trees were plastered over with cement. A considerable amount of dead wood had to be removed from several of the trees before these could be used. A 4-ply burlap band about 5 inches wide was placed around the trunk of each tree and about 2 feet from the ground. Sometimes it was necessary to place additional bands around the main branches on badly damaged trees (fig. 9), but as a rule a single band was found to be sufficient.

The bands were examined every three days and the larvæ collected from each orchard were brought to the laboratory for further observations. The details pertaining to these records will be found in Tables XXVIII to XXXI.

TABLE XXXI.—*Summary of Lake Shore, Saugatuck, and New Richmond, Mich., band record experiments of 1910.*

| Observations. | Lake Shore. | | Saugatuck. | | New Richmond. | |
|---|---|---|---|---|---|---|
| | Total. | Per cent. | Total. | Per cent. | Total. | Per cent. |
| Larvæ collected from bands | 985 | 100.0 | 788 | 100.0 | 543 | 100.0 |
| Moths emerging: | | | | | | |
| 1910 | 262 | 41.0 | 201 | 25.5 | 153 | 28.2 |
| 1911 | 377 | 59.0 | 313 | 39.7 | 137 | 25.2 |
| 1910–1911 | 639 | 64.8 | 514 | 65.2 | 290 | 53.4 |
| Parasitized larvæ | 75 | 7.6 | 37 | 4.7 | 42 | 7.7 |
| Winter-killed and injured larvæ | 271 | 27.5 | 237 | 30.1 | 207 | 38.1 |
| Larvæ of the first brood | 860 | 87.3 | 577 | 73.2 | 479 | 88.2 |
| Transforming larvæ of the first brood | 262 | 30.5 | 201 | 34.8 | 153 | 31.9 |
| Wintering larvæ of the first brood | 598 | 69.5 | 376 | 65.2 | 326 | 68.1 |
| Larvæ of the second brood | 125 | 12.7 | 211 | 26.8 | 64 | 11.8 |

On examining the curves of figure 10, showing the results of the band experiments, it will be noted that the two broods of larvæ overlap and can not be definitely determined from these experiments alone. With special reference to the Saugatuck experiments the hypothetical curves in figure 10 which have been drawn to represent the two broods are based on the following considerations: The last moth of the spring brood emerged July 27; it required at that time of the season 45 days from the date of emergence of the moth to time of maturity of the resulting larva. Thus the larvæ of the first brood must have ceased to appear by September 10. The first moth of the first brood or summer moth emerged July 29, at which time the insect developed rapidly and mature larvæ resulted in 33 days. Thus the first larvæ of the second brood appeared August 31. Similarly, the first-brood and second-brood larvæ in the Lake Shore and New Richmond experiments have been determined, with due consideration given to the seasonal conditions of each locality.

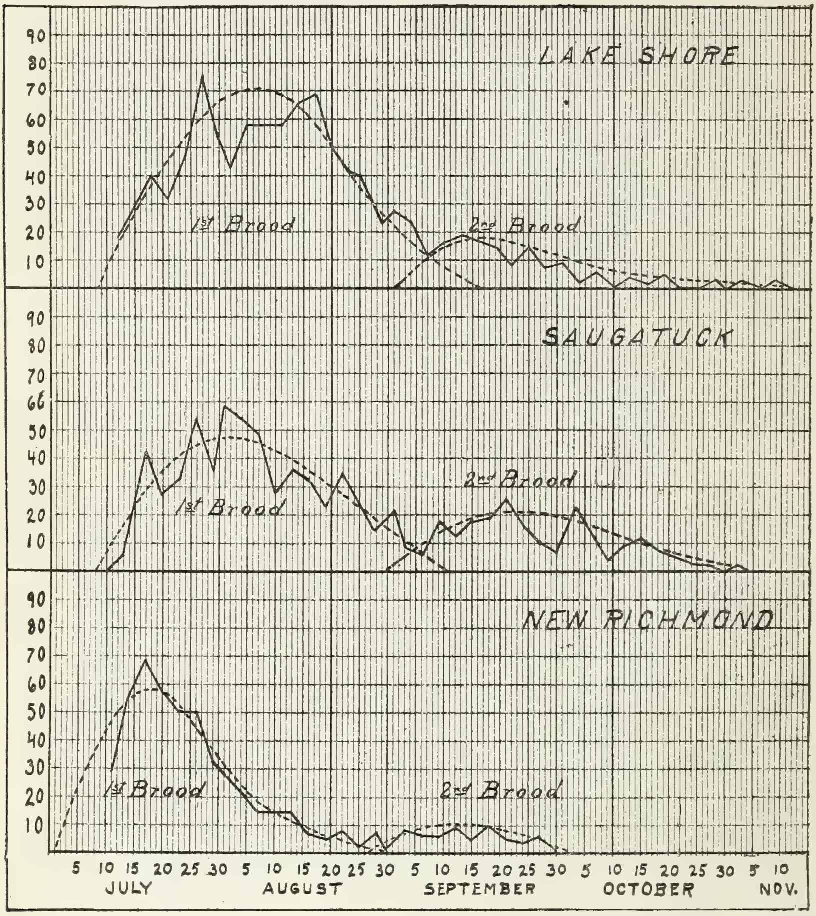

FIG. 10.—Curves made from band-record experiments in orchards at the lake shore near Douglas, at Saugatuck, and at New Richmond, Mich., 1910. (Original.)

The results from three band experiments may be appreciated by an examination of the curves in figure 10. A difference in the time and rate of maturity of larvæ will be noted in considering the height of the curves representing the first brood. In the Lake Shore orchard the maximum occurred August 8, in the Saugutuck orchard July 31, and in the New Richmond orchard July 18. It will not be possible to compare the dates for the appearance of first larvæ of the first brood, since the New Richmond experiments commenced slightly after the larvæ began to appear.

At the Lake Shore band experiments larvæ were collected in great numbers during the month of August, whereas at New Richmond only a few were obtained. There is only a slight difference in the time of appearance of the earliest second-brood larvæ in these localities, which would indicate the existence of a tendency on the part of the seasonal conditions to become equalized or uniform over the fruit belt at midsummer. At the Lake Shore orchard larvæ continued to appear one month later than in the New Richmond orchard. Part of this difference was due to the scarcity of fruit at New Richmond, but also partly because of prevailing higher temperature during the fall near the lake, which prolonged the season in the latter locality.[1] Though limited in scope, the results of these band experiments show that the codling moth varies in the time of its development in these three localities in close relation to existing climatic conditions, thus indicating that the insect must be governed by the same climatic conditions that govern the plants, and it must be due to this fact that we find a corresponding difference in the time of activity of the insect in the spring, as is noted in the time of blossoming of apples in the different sections of the fruit belt.

Of the total number of larvæ of the Saugatuck band experiment 73.2 per cent pertained to the first brood and 26.8 per cent to the second brood. Of the first-brood larvæ 34.8 per cent transformed the same season, and 65.2 per cent wintered in the larval stage. Of the total number of larvæ, 25.5 per cent developed into moths in 1910 and 39.7 per cent in 1911. Parasitism by *Ascogaster carpocapsæ* affected 4.7 per cent, and 30.1 per cent died during the winter, killed by cold.

### SUMMARY OF SEASONAL-HISTORY STUDIES OF 1910.

Figure 11 represents graphically the main results of the seasonal-history studies of 1910 and can better be appreciated from the diagram than by description.

Except for the prolonged pupal period during the very abnormal spring of 1910 the insect developed fairly normally so that from the point of view of the activities of the codling moth the season may be taken to have been about average.

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[1] For a more thorough test, records should be taken on temperature, time of blossoming of apples, and time of emergence of spring brood of moths in the different sections in the fruit belt.

## SEASONAL-HISTORY STUDIES OF 1911.

The results of the 1911 life-history studies of the codling moth are in many respects similar to those obtained during the previous year.

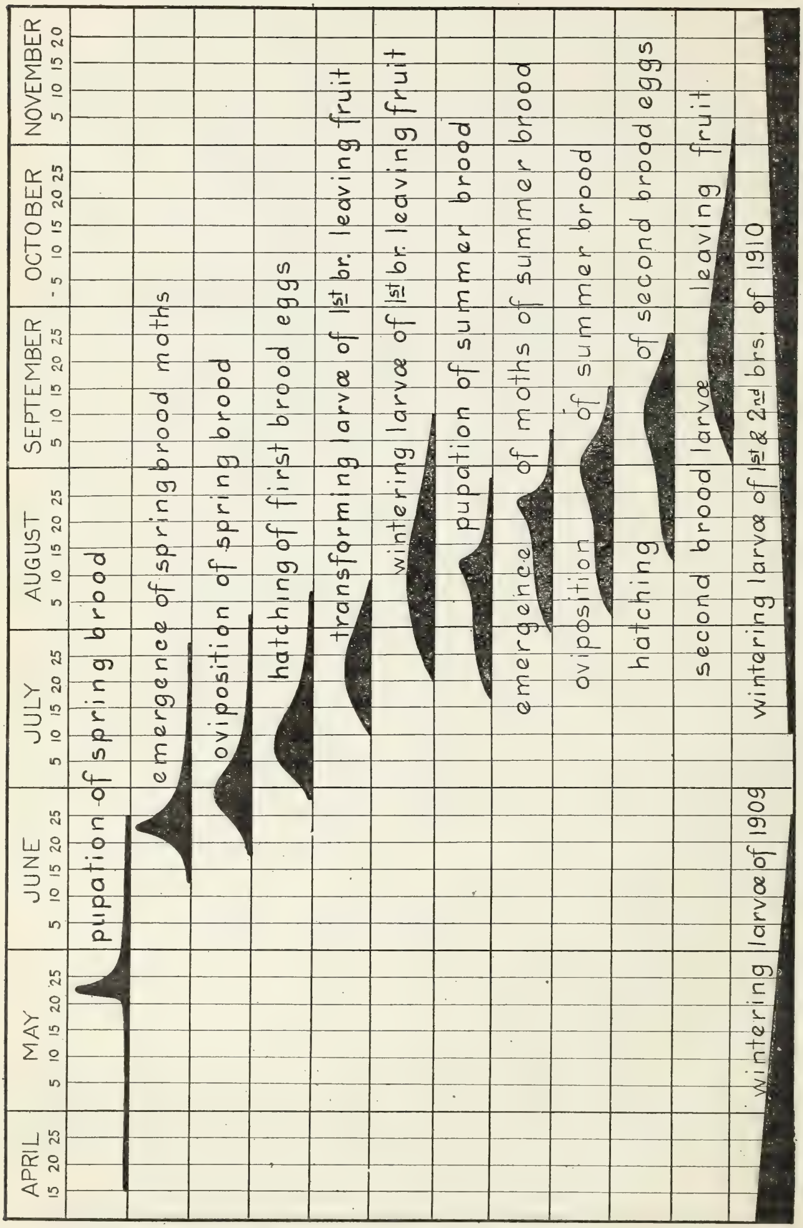

FIG. 11.—Diagram to illustrate seasonal history of the codling moth as observed during 1910, at Douglas Mich. (Original.)

The main difference is that found in the time of transformation and date of appearance of the different stages, which is ascribed to the prevalence of a very unusually high temperature during the spring and summer. To a certain extent the 1911 life-history studies constitute a test upon the 1910 investigation and in addition show the behavior of the codling moth under the above climatic conditions.

In the presentation of the observations made during 1911 on the codling moth the same plan has been followed as for 1910, and many of the details concerning methods and tabulation previously described apply equally to the 1911 studies.

TABLE XXXII.—*Time of pupation in the spring of 1911.*

| Date of pupation. | Number of pupæ. | Date of pupation. | Number of pupæ. | Date of pupation. | Number of pupæ. | Date of pupation. | Number of pupæ. |
|---|---|---|---|---|---|---|---|
| May 9 | 1 | May 22 | 10 | June 2 | 2 | June 14 | 3 |
| May 11 | 1 | May 23 | 8 | June 3 | 2 | June 15 | 1 |
| May 12 | 1 | May 24 | 8 | June 4 | 3 | June 16 | 1 |
| May 14 | 6 | May 25 | 7 | June 5 | 5 | June 17 | 3 |
| May 15 | 7 | May 26 | 5 | June 6 | 4 | June 19 | 2 |
| May 16 | 2 | May 27 | 8 | June 7 | 2 | June 21 | 1 |
| May 17 | 8 | May 28 | 9 | June 8 | 2 | June 22 | 1 |
| May 18 | 12 | May 29 | 6 | June 9 | 7 | June 26 | 1 |
| May 19 | 16 | May 30 | 7 | June 10 | 6 | | |
| May 20 | 14 | May 31 | 11 | June 11 | 4 | | |
| May 21 | 11 | June 1 | 3 | June 13 | 1 | | |

Total pupæ, 212.

## SOURCE OF REARING MATERIAL.

The rearing material in the spring of 1911 consisted of wintering larvæ, which in a normal way had entered hibernation the previous season. Practically all of the larvæ were from band records and represented the normal proportion of both first-brood and second-brood larvæ. The wintering cocoons were made between narrow strips of wood (fig. 4) and in pieces of corrugated paper (fig. 17). During the winter larvæ were kept in an outdoor shelter.

## WINTER-KILLED LARVÆ.

The percentage of larvæ killed by cold during the winter proved to be equally as high during 1911 as observed in 1910. After the completion of the different band-record observations the results show the following percentages of winter-killed larvæ:

| | Per cent. |
|---|---|
| New Richmond band records | 38.1 |
| Saugatuck band records | 30 |
| Lake Shore band records | 27.5 |

From these figures should be substracted a small number of larvæ injured in the course of transportation from the field to the laboratory. Those from New Richmond showing the highest percentage of mortality were sent in boxes through the mail and suffered more or less under transportation.[1] The larvæ from the Lake Shore and Saugatuck orchards, however, were all carefully handled, and the results of these observations show approximately the normal proportion of winter-killed larvæ.

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[1] During 1911 an improvement was made in the method of shipping the larvæ from the distant localities of the band records, by the use of mailing tubes (see page 61 and fig. 17).

### SPRING BROOD OF PUPÆ.

*Time of pupation.*—In the rearing cages pupation commenced on May 9, reached a maximum May 19, and terminated June 26 (Table XXXII). The relative rate of pupation is illustrated by a curve in figure 12. It will here be observed that pupation occurred rather irregularly and that the time when the larger number of individuals pupated extended over a longer period than in 1910. This, of course, had a direct bearing upon the time and rate of emergence of the moths of the spring brood, which, like the pupæ, appeared very irregularly.

TABLE XXXIII.—*Length of pupal stages of the spring brood, Douglas, Mich., 1911.*

| No. | Pupated. | Emerged. | Days. | No. | Pupated. | Emerged. | Days. | No. | Pupated. | Emerged. | Days. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | May 14 | May 29 | 15 | 42 | May 21 | June 10 | 20 | 83 | May 29 | June 19 | 21 |
| 2 | ...do..... | ...do..... | 15 | 43 | ...do..... | June 9 | 19 | 84 | ...do..... | ...do.... | 21 |
| 3 | ...do..... | May 30 | 16 | 44 | ...do..... | June 10 | 20 | 85 | May 30 | June 20 | 21 |
| 4 | May 15 | May 28 | 13 | 45 | May 22 | June 14 | 23 | 86 | ...do..... | June 18 | 19 |
| 5 | ...do..... | May 30 | 15 | 46 | ...do..... | June 11 | 20 | 87 | ...do..... | June 19 | 20 |
| 6 | May 16 | ...do..... | 14 | 47 | ...do..... | June 10 | 19 | 88 | May 31 | June 21 | 21 |
| 7 | ...do..... | June 6 | 21 | 48 | ...do..... | June 9 | 18 | 89 | ...do..... | ...do..... | 21 |
| 8 | May 17 | June 2 | 16 | 49 | ...do..... | June 10 | 19 | 90 | ...do..... | June 20 | 20 |
| 9 | ...do..... | June 3 | 17 | 50 | May 23 | ...do..... | 18 | 91 | ...do..... | June 19 | 19 |
| 10 | ...do..... | ...do..... | 17 | 51 | ...do..... | ...do..... | 18 | 92 | ...do..... | June 20 | 20 |
| 11 | ...do..... | June 10 | 24 | 52 | ...do..... | June 11 | 19 | 93 | June 1 | ...do..... | 19 |
| 12 | ...do..... | June 2 | 16 | 53 | ...do..... | June 10 | 18 | 94 | June 2 | June 22 | 20 |
| 13 | May 18 | June 3 | 16 | 54 | May 24 | June 6 | 13 | 95 | ...do..... | June 21 | 19 |
| 14 | ...do..... | ...do..... | 16 | 55 | ...do..... | June 9 | 16 | 96 | June 3 | June 22 | 19 |
| 15 | ...do..... | June 6 | 19 | 56 | ...do..... | June 10 | 17 | 97 | ...do..... | June 21 | 18 |
| 16 | ...do..... | June 4 | 17 | 57 | ...do..... | June 11 | 18 | 98 | June 4 | June 23 | 19 |
| 17 | ...do..... | June 5 | 18 | 58 | ...do..... | June 14 | 21 | 99 | ...do..... | June 24 | 20 |
| 18 | ...do..... | June 4 | 17 | 59 | ...do..... | June 11 | 18 | 100 | June 5 | June 23 | 18 |
| 19 | ...do..... | June 5 | 18 | 60 | May 25 | June 12 | 18 | 101 | ...do..... | ...do..... | 18 |
| 20 | May 19 | June 6 | 18 | 61 | ...do..... | June 14 | 20 | 102 | ...do..... | June 24 | 19 |
| 21 | ...do..... | June 5 | 17 | 62 | ...do..... | ...do..... | 20 | 103 | ...do..... | ...do..... | 19 |
| 22 | ...do..... | ...do..... | 17 | 63 | ...do..... | June 12 | 18 | 104 | June 6 | June 23 | 17 |
| 23 | ...do..... | ...do..... | 17 | 64 | ...do..... | June 14 | 20 | 105 | ...do..... | June 24 | 18 |
| 24 | ...do..... | ...do..... | 17 | 65 | ...do.... | June 12 | 18 | 106 | June 8 | ...do..... | 16 |
| 25 | ...do..... | June 6 | 18 | 66 | May 26 | June 16 | 21 | 107 | June 9 | June 25 | 16 |
| 26 | ...do..... | June 4 | 16 | 67 | ...do..... | June 15 | 20 | 108 | ...do..... | June 27 | 18 |
| 27 | ...do..... | June 5 | 17 | 68 | ...do..... | June 14 | 19 | 109 | ...do..... | June 26 | 17 |
| 28 | ...do..... | June 6 | 18 | 69 | ...do..... | ...do..... | 19 | 110 | ...do..... | ...do..... | 17 |
| 29 | ...do..... | June 4 | 16 | 70 | May 27 | June 15 | 19 | 111 | June 10 | ...do..... | 16 |
| 30 | ...do..... | June 7 | 19 | 71 | ...do..... | June 16 | 20 | 112 | ...do..... | June 27 | 17 |
| 31 | ...do..... | June 6 | 18 | 72 | ...do..... | June 19 | 23 | 113 | ...do..... | ...do..... | 17 |
| 32 | May 20 | June 9 | 20 | 73 | ...do..... | June 15 | 19 | 114 | ...do..... | ...do..... | 17 |
| 33 | ...do..... | June 8 | 19 | 74 | ...do..... | June 16 | 20 | 115 | June 11 | June 30 | 19 |
| 34 | ...do..... | June 9 | 20 | 75 | May 28 | June 18 | 21 | 116 | June 13 | ...do..... | 17 |
| 35 | ...do..... | June 8 | 19 | 76 | ...do..... | ...do..... | 21 | 117 | June 14 | ...do..... | 16 |
| 36 | ...do..... | June 7 | 18 | 77 | ...do..... | ...do..... | 21 | 118 | ...do..... | July 8 | 24 |
| 37 | ...do..... | June 8 | 19 | 78 | ...do..... | ...do..... | 21 | 119 | June 15 | July 2 | 17 |
| 38 | ...do..... | ...do..... | 19 | 79 | ...do..... | June 17 | 20 | 120 | June 17 | June 30 | 13 |
| 39 | May 21 | June 10 | 20 | 80 | ...do..... | June 18 | 21 | 121 | ...do..... | July 2 | 15 |
| 40 | ...do..... | June 8 | 18 | 81 | May 29 | ...do..... | 20 | 122 | June 21 | July 5 | 14 |
| 41 | ...do..... | June 10 | 20 | 82 | ...do..... | June 19 | 21 | | | | |
| Average | | | | | | | | | | | 18.41 |
| Maximum | | | | | | | | | | | 24 |
| Minimum | | | | | | | | | | | 13 |

*Length of pupal stage.*—Owing to the very variable climatic conditions during the pupal period there resulted a considerable difference in the length of the pupal stage. The observations for the spring brood extended from May 14 to July 8, during which time records were taken from 122 individual insects.

TABLE XXXIV.—*Length of pupal stages of the spring brood; summary of Table XXXIII.*

| Number of observations. | Pupal period. | Number of observations. | Pupal period. | Number of observations. | Pupal period. |
|---|---|---|---|---|---|
| | *Days.* | | *Days.* | | *Days.* |
| 3 | 13 | 18 | 17 | 14 | 21 |
| 2 | 14 | 22 | 18 | 2 | 23 |
| 4 | 15 | 23 | 19 | 2 | 24 |
| 12 | 16 | 20 | 20 | | |

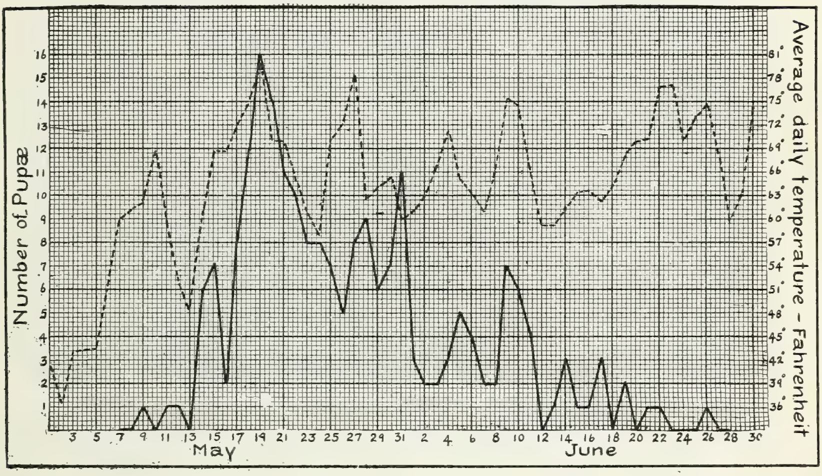

FIG. 12.—Curve of spring pupation of the codling moth in 1911, at Douglas, Mich. (Original.)

The results are given in Table XXXIII and are further summarized in Table XXXIV. The average length of the pupal stage was 18.4 days, the minimum length 13 days, and the maximum 24 days.

*Relation of temperature to the duration of the pupal stage.*—From general observations it has long been known that the temperature has a marked effect upon the duration of the pupal stage. The intimacy of this relation has already been pointed out by different investigators and most recently by Prof. E. D. Sanderson in a paper on the relation of temperature to the growth of insects.[1]

In our tentative effort to find the existing relation of the temperature to the length of the pupal period at Douglas, Mich., the average temperature has been taken from the average daily temperature during the pupal stage of a number of individual insects. These averages were computed from the temperature records of Table LXX, which are from a self-recording thermometer of the type used by the United States Weather Bureau. The instrument was regulated in accordance with a mercury thermometer and was kept in the rearing shelter throughout the season. The records in Table XXXIII give the date of pupation and the date of emergence of moths for 122 individual insects.

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[1] Journ. Econ. Ent., III, p. 113, 1910.

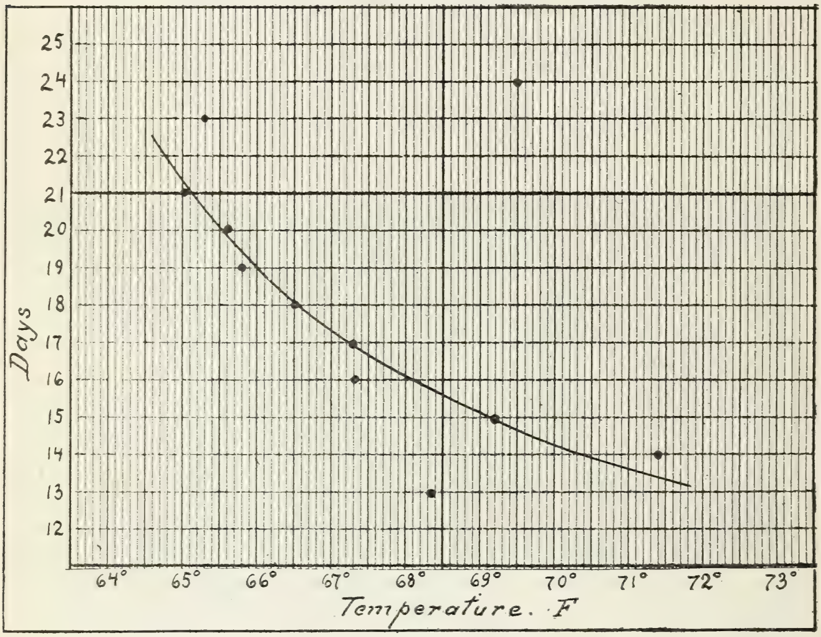

FIG. 13.—Curve showing relation of temperature to the duration of the pupal stage in the spring brood of the codling moth; Douglas, Mich., 1911 (from Table XXXV). (Original.)

TABLE XXXV.—*Average daily temperature during the pupal periods of the spring broods; summary of Table XXXIII.*

| Pupal period. | No. of observations. | Average mean temperature. | | | Pupal period. | No. of observations. | Average mean temperature. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Average. | Maximum. | Minimum. | | | Average. | Maximum. | Minimum. |
| *Days.* | | ° *F.* | ° *F.* | ° *F.* | *Days.* | | ° *F.* | ° *F.* | ° *F.* |
| 13 | 3 | 68.31 | 69.86 | 66.02 | 19 | 23 | 65.84 | 67.29 | 64.48 |
| 14 | 2 | 71.41 | 73.77 | 69.06 | 20 | 20 | 65.65 | 66.81 | 64.53 |
| 15 | 4 | 69.19 | 70.08 | 68.83 | 21 | 14 | 65.01 | 67.58 | 64.49 |
| 16 | 12 | 67.29 | 68.56 | 65.51 | 23 | 2 | 65 33 | 65.61 | 65.05 |
| 17 | 18 | 67.32 | 69.29 | 66.06 | 24 | 2 | 69.52 | 71.73 | 67.32 |
| 18 | 22 | 66.50 | 68.23 | 65.26 | | | | | |

Observations on the time of transformation were made once daily and invariably in the afternoon. In Table XXXV a summary of these temperature records is given showing the averages for each day and also the number of individual pupæ under observation for the respective days. To show the extent of variation in results obtained, the maximum and minimum of average temperatures of individual pupal stages are given for the different days in the same table. On examining the diagram of figure 13 it will be noted that where the averages have been made from a large number of observations the results are fairly uniform. These results here show a marked decrease in the time of the pupal stage with an increase of temperature. Considering the curve of this figure we get the following readings:

| | °F | | °C |
|---|---|---|---|
| For the 15 days pupal stage | 69.2 | or | 20.6 |
| For the 17 days pupal stage | 67.3 | or | 19.6 |
| For the 19 days pupal stage | 66.0 | or | 18.9 |
| For the 21 days pupal stage | 65.1 | or | 18.4 |

It should be remembered that besides the temperature there are other factors affecting the development of the insects. Moisture and the physical condition of individual insects, etc., naturally tend to cause variation in the length of the pupal stage, and to these factors may be ascribed certain variations in the results obtained.

## SPRING BROOD OF MOTHS.

*Time of emergence of moths.*—The earliest moths, emerging May 26, were about normal in the date of appearance. Subsequently, however, and for the rest of the emergence period, the moths appeared very irregularly and for a longer period than usual. At the height of the emergence, during the middle part of June, two fairly long delays were caused by prevailing rains and a drop of temperature, so that the emergence period, as shown in figure 14, became marked by two distinct maximums. The records for the emergence of 1,127 moths are given in Table XXXVI. The first moth of the summer brood emerged July 7 and the last moth of the spring brood emerged July 8, thus causing the emergence periods of the two broods to overlap.

TABLE XXXVI.—*Time of emergence of moths of the spring brood, Douglas, Mich., 1911.*

| Date of emergence. | Total emergence. | Date of emergence. | Total emergence. | Date of emergence. | Total emergence. | Date of emergence. | Total emergence. |
|---|---|---|---|---|---|---|---|
| May 25 | ........ | June 6 | 47 | June 18 | 44 | June 30 | 16 |
| May 26 | 1 | June 7 | 30 | June 19 | 53 | July 1 | 7 |
| May 27 | 11 | June 8 | 68 | June 20 | 44 | July 2 | 7 |
| May 28 | 6 | June 9 | 52 | June 21 | 41 | July 3 | 2 |
| May 29 | 19 | June 10 | 62 | June 22 | 54 | July 4 | 1 |
| May 30 | 12 | June 11 | 35 | June 23 | 56 | July 5 | 10 |
| May 31 | 10 | June 12 | 20 | June 24 | 45 | July 6 | ........ |
| June 1 | 3 | June 13 | 2 | June 25 | 23 | July 7 | ........ |
| June 2 | 29 | June 14 | 48 | June 26 | 37 | July 8 | 1 |
| June 3 | 49 | June 15 | 20 | June 27 | 22 | | |
| June 4 | 49 | June 16 | 16 | June 28 | 4 | | |
| June 5 | 43 | June 17 | 15 | June 29 | 13 | | |

Total, 1,127 moths.

*Egg deposition by individual moths.*—Already during 1910 several experiments had been made to determine the number of eggs deposited by a single female. The results from these observations were, however, limited to a few females and could not be considered conclusive. Further efforts were therefore made in 1911 to obtain additional data on this question. Many difficulties have been encountered in getting moths that will oviposit in captivity. The obstacles have probably been due to the fact that mating had not taken place, it being difficult to find the insects in copulation or to bring about mating by confining together single pairs of male and female moths. In the stock-jar cages, where a number of male and female insects have been confined, eggs have always resulted in abundance and mating must have occurred quite generally though it was only observed on rare occasions. It was therefore planned to remove female moths from the stock jars after the moths had been confined together two or three days, and prior to any egg deposition in the stock jars.

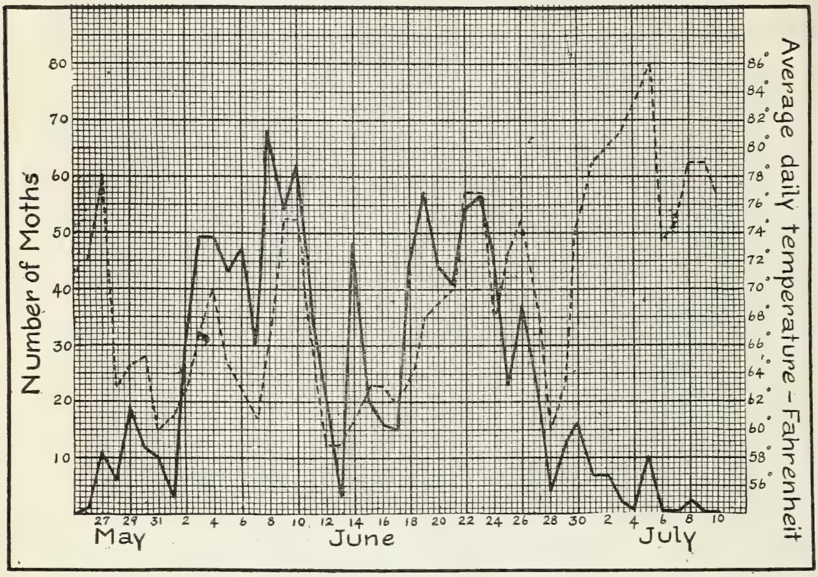

FIG. 14.—Emergence curve of moths of the spring brood in 1911, at Douglas, Mich. (Original.)

TABLE XXXVII.—*Egg deposition in confinement by individual moths of the spring brood, Douglas, Mich., 1911.*

| Date of egg deposition. | Number of individual moths. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | Date of emergence of moths. | | | | | | | | | | | |
| | June 4. | June 4. | June 6. | June 11. | June 11. | June 20. | June 20. | June 24. | June 24. | June 26. | June 26. | June 26. |
| June 10 | | | 26 | | | | | | | | | |
| June 11 | 1 | 11 | | | | | | | | | | |
| June 12 | | | | | | | | | | | | |
| June 13 | | | | | | | | | | | | |
| June 14 | | | | | | | | | | | | |
| June 15 | | | | | | | | | | | | |
| June 16 | | | | | | | | | | | | |
| June 17 | | | | 1 | 33 | | | | | | | |
| June 18. | 10 | | | 8 | 4 | | | | | | | |
| June 19 | 2 | 24 | | 7 | 37 | | | | | | | |
| June 20 | 2 | | | 20 | 35 | | | | | | | |
| June 21 | 20 | | | | 3 | | | | | | | |
| June 22 | 8 | | | | 14 | | | | | | | |
| June 23 | 14 | | | | 35 | | | | | | | |
| June 24 | | | | | | | 6 | | | | | |
| June 25 | 10 | | | | | | 26 | | | | | |
| June 26 | 3 | | | | | | | | | | | |
| June 27 | | | | | | | | | | | | |
| June 28 | | | | | | | | | 17 | | | |
| June 29 | | | | | | 28 | | 58 | | 2 | | |
| June 30 | | | | | | 4 | | 28 | 56 | 7 | | |
| July 1 | | | | | | 3 | | | 13 | 40 | 1 | |
| July 2 | | | | | | | | | 15 | | 14 | |
| July 3 | | | | | | | | | 1 | | | |
| July 4 | | | | | | | | | | | | 5 |
| July 5 | | | | | | | | | | | | 33 |
| | Date of death of moths. | | | | | | | | | | | |
| | July 1. | June 21. | June 10. | (1) | June 25. | July 2. | June 28. | July 8. | July 6. | July 6. | July 6. | July 8. |

[1] Escaped June 20.

In all 160 female moths were removed from the different stock jars (Table XL) and were kept isolated in glass tumblers, covered with perforated tin covers. A small piece of sponge dipped in diluted sugar-and-honey solution was inserted to supply food. To encourage egg deposition fresh pear leaves were placed in the tumblers and were daily replaced by fresh foliage at the time the tumblers were examined for eggs.

TABLE XXXVIII.—*Egg deposition by individual moths; summary of Table XXXVII.*

| Observations. | Number of individual moths. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Total eggs per female | 70 | 35 | 26 | 36 | 161 | 35 | 32 | 86 | 102 | 49 | 15 | 38 |
| Days before egg deposition | 7 | 7 | 4 | 6 | 6 | 9 | 4 | 5 | 4 | 3 | 5 | 8 |
| Days duration of egg deposition | 16 | 9 | 1 | 4 | 7 | 3 | 2 | 2 | 6 | 3 | 2 | 2 |
| Days alive after egg deposition | 5 | 2 | 0 | ...... | 2 | 1 | 3 | 8 | 3 | 5 | 4 | 3 |
| Days moth lived | 27 | 17 | 4 | ...... | 14 | 12 | 8 | 14 | 12 | 10 | 10 | 12 |

Table XXXIX.—*Egg deposition by individual moths; summary of Tables XXXVII and XXXVIII.*

| Observations. | Average. | Maximum. | Minimum. |
|---|---|---|---|
| Eggs per female | 57.08 | 161 | 15 |
| Eggs per day per female | 16.31 | 58 | 1 |
| Days before egg deposition per female | 5.66 | 9 | 3 |
| Days of egg deposition per female | 4.75 | 16 | 1 |
| Days moths lived after egg deposition | 3.27 | 8 | 0 |
| Days moths lived | 12.72 | 27 | 4 |

From the 160 separate experiments only 12 yielded results worth recording, and these are given in Tables XXXVII–XXXIX. The following observations are recorded in Table XXXVII: The time of emergence of the different moths, the time and amount of egg deposition per female, and the date of death of each of the female moths. In Table XXXVIII a summary of results will be found showing the number of eggs per female, the number of days before egg deposition, the duration of egg deposition, and the length of life of the moths. It will be noted that on an average these moths commenced to oviposit 5.6 days after their emergence; the maximum length of this period was 9 days and the minimum 3 days. Egg deposition extended on an average over a period of 5 days. The average number of eggs per female was 57.08, the maximum number of eggs per female 161, and the minimum 15 eggs per female. The moths lived, on an average, 3.2 days after egg deposition; in one instance death followed the day after the last oviposition; on the other extreme a single moth lived 8 days after the last egg deposition.

The conditions under which it was necessary to keep these moths for observation were of course quite abnormal and it is doubtful whether all of the moths deposited the normal number of eggs. It is the writer's opinion that in the field the average number of eggs per female is considerably higher and may reach an average of 75 to 85 eggs per female.

*Egg deposition in stock-jar experiments.*—The nature of the stock-jar tests has already been described on page 13. As will be found in Table XL, the observations merely cover the date of emergence of moths in each cage and the date of the first and last egg depositions per jar, which give only an idea of the extent of the oviposition period. We find from these data that on an average the first eggs were laid four days after the date of emergence of the moths.

TABLE XL.—*Oviposition by moths of the spring brood in rearing cages, Douglas, Mich., 1911.*

| Cage No. | Number of moths. | Date of— | | | Number of days— | | |
|---|---|---|---|---|---|---|---|
| | | Emergence of moths. | First oviposition. | Last oviposition. | Before oviposition. | Duration of oviposition. | From date of emergence to last oviposition. |
| 1 | 13 | May 24 | May 28 | June 14 | 4 | 18 | 21 |
| 2 | 20 | May 29 | June 3 | June 21 | 5 | 19 | 23 |
| 3 | 9 | May 30 | June 10 | June 10 | 11 | 1 | 11 |
| 4 | 10 | May 31 | June 6 | June 8 | 6 | 3 | 8 |
| 5 | 5 | June 1 | ...do..... | June 9 | 5 | 4 | 8 |
| 6 | 29 | June 2 | ...do..... | ...do..... | 4 | 4 | 7 |
| 7 | 39 | June 3 | June 5 | June 21 | 2 | 17 | 18 |
| 8 | 47 | June 4 | June 8 | June 20 | 4 | 13 | 16 |
| 9 | 40 | June 5 | June 9 | June 9 | 4 | 1 | 4 |
| 10 | 43 | June 6 | ...do..... | June 24 | 3 | 16 | 18 |
| 11 | 29 | June 7 | June 10 | June 20 | 3 | 11 | 13 |
| 12 | 56 | June 8 | June 11 | June 23 | 3 | 13 | 15 |
| 13 | 45 | June 9 | June 12 | June 15 | 3 | 4 | 6 |
| 14 | 50 | June 10 | June 13 | June 22 | 3 | 10 | 12 |
| 15 | 14 | June 17 | June 22 | June 26 | 5 | 5 | 9 |
| 16 | 48 | June 19 | June 23 | June 27 | 4 | 5 | 8 |
| 17 | 38 | June 23 | June 25 | ...do..... | 2 | 3 | 4 |
| 18 | 44 | June 24 | June 27 | June 30 | 3 | 4 | 6 |
| 19 | 16 | June 25 | ...do..... | July 2 | 2 | 6 | 7 |
| Average | | | | | 4 | 8.3 | 11.3 |
| Maximum | | | | | 11 | 19 | 23 |
| Minimum | | | | | 2 | 1 | 4 |

The shortest period before first egg deposition was 2 days, and the maximum period 11 days. Within the separate cages oviposition lasted from 1 to 19 days, with an average of 8.3 days. When we consider the period from the date of emergence to the date of last oviposition we find a maximum length of time of 23 days, an average of 11.3 days, and a minimum of 4 days.

*Period of egg deposition.*—In the field egg deposition is estimated to have taken place from May 28 to July 18, with a maximum number of eggs between June 10 and June 30. This has been estimated from the records of egg deposition by moths in captivity, the time of emergence of the moths, and the band-record observations.

*Length of life of moths.*—The length of life of 153 male and 177 female moths, confined in the stock jars, is given in Table XLI. On an average the males lived 9.18 days and the females 10.63 days. The maximum length of life for the males was 18 days and for the females 23 days.

TABLE XLI.—*Length of life of male and female moths of the spring brood in captivity; summary of records of 330 individual moths, Douglas, Mich., 1911.*

| Male. | | Female. | | Male. | | Female. | |
|---|---|---|---|---|---|---|---|
| Length of life. | Number of moths. | Length of life. | Number of moths. | Length of life. | Number of moths. | Length of life. | Number of moths. |
| *Days.* | | *Days.* | | *Days.* | | *Days.* | |
| 2 | 2 | 2 | 2 | 14 | 11 | 14 | 9 |
| 3 | 2 | 3 | 4 | 15 | 8 | 15 | 13 |
| 4 | 12 | 4 | 6 | 16 | 3 | 16 | 5 |
| 5 | 11 | 5 | 5 | 17 | 2 | 17 | 5 |
| 6 | 11 | 6 | 10 | 18 | 1 | 18 | 7 |
| 7 | 14 | 7 | 13 | .......... | .......... | 19 | 4 |
| 8 | 18 | 8 | 18 | .......... | .......... | 20 | 2 |
| 9 | 15 | 9 | 20 | .......... | .......... | 21 | 1 |
| 10 | 16 | 10 | 22 | .......... | .......... | 23 | 1 |
| 11 | 11 | 11 | 13 | | | | |
| 12 | 15 | 12 | 14 | | 153 | | 177 |
| 13 | 1 | 13 | 3 | | | | |

TABLE XLII.—*Length of life of male and female moths of the spring brood in captivity, Douglas, Mich., 1911; summary of Table XLI.*

| Observations. | Life of male moths. | Life of female moths. |
|---|---|---|
| | *Days.* | *Days.* |
| Average | 9.18 | 10.63 |
| Maximum | 18 | 23 |
| Minimum | 2 | 2 |

It is of interest to note that in this brood, as well as in the summer brood, the females were more numerous than the males and survived the males on an average by about two days.

## THE FIRST GENERATION

### FIRST BROOD OF EGGS.

*Length of incubation.*—Observations on the length of incubation extended over the greatest period when eggs occurred in the field (Table XLIII). The high temperature which at times prevailed brought the minimum length of incubation down to 4 days, against 6 days for the same brood in 1910. The average length of incubation for the brood was 8 days, the maximum 10 days. Observations on the embryological development of the eggs were also taken as recorded in Table XLIII. The so-called "red ring" generally appeared 3 days after egg deposition, and the "black spot" 2 days previous to hatching.

TABLE XLIII.—*Length of incubation of the first brood of eggs and average mean temperature during incubation, Douglas, Mich., 1911.*

| No. of observation. | No. of eggs. | Date— | | | | Duration of— | | | Average mean temperature. |
|---|---|---|---|---|---|---|---|---|---|
| | | Deposited. | Red ring. | Black spot. | Hatched. | Red ring. | Black spot. | Incubation. | |
| | | | | | | *Days.* | *Days.* | *Days.* | *F.°* |
| 1 | ........ | May 28 | June 1 | June 5 | June 7 | 4 | 8 | 10 | 64.27 |
| 2 | ........ | May 30 | June 3 | June 8 | June 9 | 4 | 9 | 10 | 64.21 |
| 3 | ........ | June 1 | June 4 | ...do..... | June 10 | 3 | 7 | 9 | 65.79 |
| 4 | ........ | June 4 | June 7 | June 11 | June 12 | 3 | 7 | 8 | 67.78 |
| 5 | ........ | June 3 | June 6 | June 10 | June 11 | 3 | 7 | 8 | 67.87 |
| 6 | ........ | June 5 | June 8 | .......... | June 13 | 3 | ...... | 8 | 66.38 |
| 7 | ........ | June 6 | .......... | .......... | June 15 | ...... | ...... | 9 | 65.07 |
| 8 | 14 | June 8 | June 11 | June 15 | June 17 | 3 | 7 | 9 | 65.27 |
| 9 | 81 | June 9 | June 12 | June 16 | ...do..... | 3 | 7 | 8 | 65.30 |
| 10 | 15 | ...do..... | ...do..... | ...do..... | June 18 | 3 | 7 | 9 | 64.96 |
| 11 | 146 | June 10 | June 13 | .......... | June 19 | 3 | ...... | 9 | 63.68 |
| 12 | 15 | ...do..... | ...do..... | .......... | June 20 | 3 | ...... | 10 | 64.12 |
| 13 | 68 | June 11 | June 14 | June 18 | ...do .... | 3 | 7 | 9 | 62.93 |
| 14 | 20 | ...do..... | ...do..... | ...do..... | June 21 | 3 | 7 | 10 | 63.58 |
| 15 | 50 | June 12 | June 15 | June 19 | ...do..... | 3 | 7 | 9 | 63.29 |
| 16 | 8 | ...do..... | ...do..... | ...do..... | June 22 | 3 | 7 | 10 | 63.97 |
| 17 | 31 | June 13 | June 16 | June 20 | ...do..... | 3 | 7 | 9 | 64.50 |
| 18 | 46 | June 14 | June 18 | June 21 | ...do..... | 4 | 7 | 8 | 65.21 |
| 19 | 13 | ...do..... | ...do..... | ...do..... | June 23 | 4 | 7 | 9 | 66.55 |
| 20 | 51 | June 15 | June 19 | ...do..... | ...do..... | 4 | 6 | 8 | 67.18 |
| 21 | 18 | ...do..... | ...do..... | ...do..... | June 24 | 4 | 6 | 9 | 68.30 |
| 22 | 60 | June 16 | June 20 | June 22 | June 23 | 4 | 6 | 7 | 67.73 |
| 23 | 18 | ...do..... | ...do..... | ...do..... | June 24 | 4 | 6 | 8 | 68.93 |
| 24 | ........ | June 18 | June 21 | June 23 | ...do..... | 3 | 5 | 6 | 70.95 |
| 25 | 48 | June 19 | June 22 | June 24 | June 26 | 3 | 5 | 7 | 72.10 |
| 26 | 66 | June 20 | ...do..... | ...do..... | June 27 | 2 | 4 | 7 | 73.08 |
| 27 | 17 | ...do..... | ...do..... | June 25 | June 28 | 2 | 5 | 8 | 72.52 |
| 28 | 47 | June 21 | June 24 | June 26 | June 27 | 3 | 5 | 6 | 73.67 |
| 29 | 18 | June 22 | June 25 | June 27 | June 28 | 3 | 5 | 6 | 73.42 |
| 30 | 28 | June 24 | June 27 | June 30 | July 1 | 3 | 6 | 7 | 69.15 |
| 31 | 10 | June 26 | June 29 | July 1 | July 2 | 3 | 5 | 6 | 70.07 |
| 32 | 52 | ...do..... | ...do..... | ...do..... | July 3 | 3 | 5 | 7 | 71.61 |
| 33 | 82 | June 27 | July 1 | July 3 | July 4 | 4 | 6 | 7 | 72.51 |
| 34 | 24 | June 28 | July 2 | ...do..... | ...do..... | 4 | 5 | 6 | 73.16 |
| 35 | 7 | June 29 | .......... | July 4 | July 5 | ...... | ...... | 6 | 76.96 |
| 36 | 34 | July 2 | July 4 | July 5 | July 6 | 2 | 3 | 4 | 82.80 |

TABLE XLIV.—*Incubation periods of first-brood eggs; summary of Table XLIII.*

| Appearance of red ring. | | Appearance of black spot. | | Total incubation period. | |
|---|---|---|---|---|---|
| Number of days. | Number of observations. | Number of days. | Number of observations. | Number of days. | Number of observations. |
| 2 | 3 | 3 | 1 | 4 | 1 |
| 3 | 21 | 4 | 1 | 6 | 6 |
| 4 | 10 | 5 | 8 | 7 | 6 |
| .......... | .......... | 6 | 6 | 8 | 8 |
| .......... | .......... | 7 | 13 | 9 | 10 |
| .......... | .......... | 8 | 1 | 10 | 5 |
| .......... | .......... | 9 | 1 | .......... | .......... |

TABLE XLV.—*Incubation periods of first-brood eggs; summary of Tables XLIII and XLIV.*

| Observations. | Number of days— | | |
|---|---|---|---|
| | For appearance of red ring. | For appearance of black spot. | For incubation. |
| Average | 3.206 | 6.161 | 7.944 |
| Maximum | 4 | 9 | 10 |
| Minimum | 2 | 3 | 4 |

TABLE XLVI.—*Average mean temperature during incubation of first brood of eggs, 1911; summary of Table XLIII.*

| Number of observations. | Days of incubation. | Average mean temperature. | | |
|---|---|---|---|---|
| | | Average. | Maximum. | Minimum. |
| | | °*F.* | °*F.* | °*F.* |
| 1 | 4 | 82.80 | | |
| 6 | 6 | 73.04 | 76.96 | 70.07 |
| 6 | 7 | 71.03 | 73.08 | 67.73 |
| 8 | 8 | 67.65 | 72.52 | 65.21 |
| 10 | 9 | 65.03 | 68.30 | 62.93 |
| 5 | 10 | 64.03 | 64.27 | 63.58 |

*Effect of temperature upon time of incubation.*—One of the greatest factors affecting the time of incubation is the temperature. This is fully shown from the results of the temperature records for the time of incubation both for the first and second broods of eggs as brought out in the curve of figure 15.

Because of the similarity of results obtained, the two broods of eggs are here considered together. The same methods of computing results have been followed as for the spring brood of pupæ (p. 10). In Tables XLIII and LVII the average mean temperature is given for the time of incubation for the different sets of eggs. These data have been summarized into averages under the respective days of the hatching periods. (Tables XLVI and LX.) The curve of figure 15 has been plotted from these combined data, and shows a marked shortening of time under a prevailing high temperature and a prolongation of time under prevailing low temperature.

Taking our readings directly from the curve of figure 15 we get the following average degrees of temperature for the different number of days of incubation:

4 days=83.6° F. or 28.7° C.
5 days=77.0° F. or 25.0° C.
6 days=72.8° F. or 22.8° C.
7 days=70.0° F. or 21.1° C.
8 days=67.5° F. or 19.7° C.
9 days=65.5° F. or 18.6° C.
10 days=64.0° F. or 17.8° C.
11 days=62.7° F. or 17.0° C.
12 days=61.8° F. or 16.6° C.
13 days=61.2° F. or 16.2° C.
14 days=60.6° F. or 16.0° C.
15 days=60.1° F. or 15.6° C.
16 days=59.8° F. or 15.4° C.

The eggs for these experiments were kept in the outdoor rearing shelter, subjected to the normal temperature.

It should be remembered that throughout these tests the temperature has been fluctuating and that the separate obsevations can be only approximately exact and we have therefore obtained a great latitude of variation in degrees of temperature for the respective days. The extent of this variation is shown in Tables XLVI and LX in the maximum and minimum records. Variation in the time of incubation should not entirely be ascribed to inadequate methods of recording observations but also to natural influences other than temperature. It has been constantly found that eggs deposited at the same time have varied several days in hatching. Moisture conditions no doubt also have a bearing upon the length of incubation. The writer has found that eggs do not hatch readily during the prevalence of extremely dry weather.

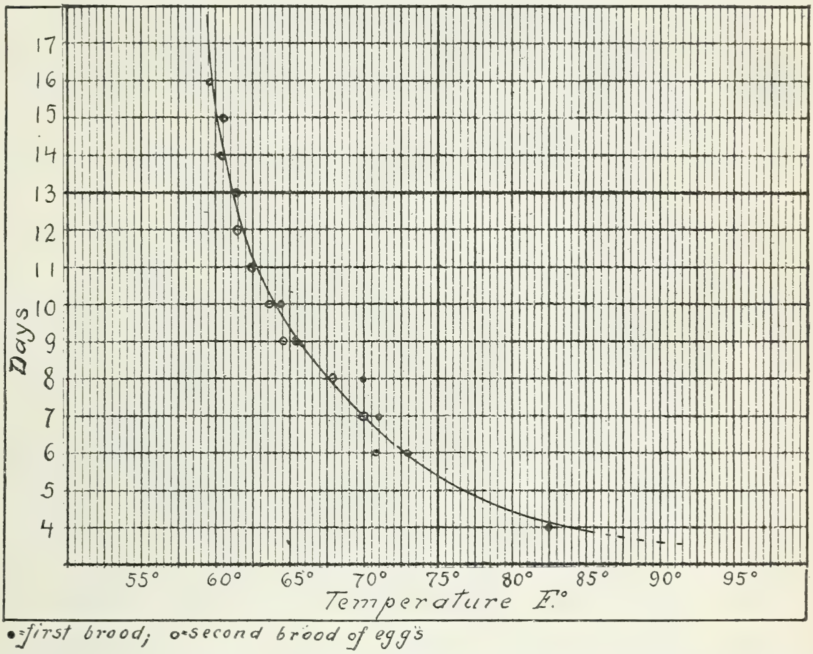

FIG. 15.—Curve showing relation of the temperature to the time of incubation of first-brood and second-brood eggs of the codling moth at Douglas, Mich., 1911. (From Tables XLIII and LVII.) (Original.)

The "critical" temperature for the eggs of the codling moth can not be determined from the present data. It is therefore not possible to establish the degrees of accumulated effective temperature required for hatching under any given degrees of temperature.

### FIRST-BROOD OF LARVÆ.

*Time of hatching.*—The earliest newly hatched larvæ appeared in the field about June 7, eggs being deposited on May 28 and the first larva from the band records being collected June 27. The greatest number of larvæ hatched between June 17 and July 7. A few isolated larvæ hatched as late as July 20.

*Length of feeding period of transforming larvæ.*—The feeding period for the transforming larvæ of the first brood was determined from 70 individuals, as given in Table LV. The average length of feeding was 21.25 days, the maximum 29 days, and the minimum 15 days. These results show a shortening of the feeding period as compared with the records for 1910, which must have been due to the exceptionally warm season of 1911.

TABLE XLVII.—*Length of feeding period of wintering larvæ of the first brood, Douglas, Mich., 1911.*

| No. of observation. | Date of— | | Days feeding. | No. of observation. | Date of— | | Days feeding. | No. of observation. | Date of— | | Days feeding. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hatching. | Leaving the fruit. | | | Hatching. | Leaving the fruit. | | | Hatching. | Leaving the fruit. | |
| 1 | June 7 | July 11 | 34 | 10 | June 22 | July 12 | 20 | 19 | June 26 | July 24 | 28 |
| 2 | June 13 | July 6 | 23 | 11 | June 23 | July 13 | 20 | 20 | ...do..... | July 28 | 32 |
| 3 | June 15 | July 12 | 27 | 12 | June 24 | July 12 | 18 | 21 | ...do..... | ...do..... | 32 |
| 4 | ...do..... | July 14 | 29 | 13 | ...do..... | July 15 | 21 | 22 | ...do..... | Aug. 3 | 38 |
| 5 | June 18 | July 12 | 24 | 14 | June 26 | July 14 | 18 | 23 | June 27 | July 24 | 27 |
| 6 | ...do..... | July 23 | 35 | 15 | ...do..... | July 18 | 22 | 24 | ...do..... | July 30 | 33 |
| 7 | ...do..... | ...do..... | 35 | 16 | ...do..... | July 19 | 23 | 25 | ...do..... | ...do..... | 33 |
| 8 | June 19 | July 19 | 30 | 17 | ...do..... | July 20 | 24 | 26 | ...do..... | Aug. 7 | 41 |
| 9 | June 20 | July 17 | 27 | 18 | ...do..... | July 23 | 27 | 27 | ...do..... | ...do..... | 41 |
| Average | | | | | | | | | | | 28.2 |
| Maximum | | | | | | | | | | | 41 |
| Minimum | | | | | | | | | | | 18 |

*Length of feeding period of wintering larvæ.*—On comparing records of the feeding period of the wintering larvæ with those of the transforming larvæ it will be noted that there is a marked difference, in that the wintering larvæ fed for a much longer period of time. The average for the wintering larvæ is 28.2 days, the maximum 41 days, and the minimum 18 days (see Table XLVII) and for the transforming larvæ the average is 21.25 days, the maximum 29 days, and the minimum 15 days (Table LV). This difference of habit of the two sets of larvæ was also observed during 1910 and has been referred to in connection with the studies for that year.

About one-half of the first-brood larvæ recorded in Table LV were reared in bagged fruit on the trees, and the other half in fruit in cages.

Within a week of the maturity of the larvæ the bagged fruit was removed from the trees and placed in cages. The average length of feeding of larvæ in bagged fruit was 20.96 days against 21.43 days for those reared in fruit in the cages, being a difference of less than half a day.

*Time of maturity of larvæ.*—From the band records the time of maturity and the relative abundance of full-grown larvæ are determined for field conditions. The Douglas band records (fig. 18) have been taken as typical and represent also the surrounding sections of the station. The first larvæ were collected June 25 and subsequently in abundance throughout the season. It is estimated that the last larvæ of the first brood appeared September 10.[1]

*Percentage of transforming and wintering larvæ.*—Table LXVIII shows that 40 per cent of the first-brood larvæ transformed and 60 per cent wintered as larvæ. The observations are from five separate band records.

*Larval life in the cocoon.*—The larval life in the cocoon is here broadly considered to be the time necessary for the making of the cocoons, and is recorded from the time the larvæ leave the fruit to the time of pupation. More closely considered, this period actually includes the time the larva searches for its hiding place and the prepupal stage, when the larva remains inactive and undergoes structural changes previous to transformation. The wintering larvæ of the first brood are not included here, as these remain in the larval stage until the following spring. The results of 132 observations (Table XLVIII) show a variation of 2 to 18 days and an average of 7.2 days. The data for the extremely short periods of making of cocoons are somewhat misleading in that certain larvæ in the act of making the cocoons have been disturbed by others and have then abandoned the first cocoon and made a new one. The records of Table XLVIII in such instances only show the time for the making of the last cocoon. The prolonged period of time as found in some cases is probably due to a diseased condition of these larvæ.

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[1] For methods of determining the time of appearance of the last larvæ of the first brood and the first larvæ of the second brood see page 15.

TABLE XLVIII.—*Length of the pupal stage of the summer brood, Douglas, Mich., 1911.*

| No. of observation. | Date of— | | | Days— | | No. of observation. | Date of— | | | Days— | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Leaving fruit. | Pupation. | Emergence of moth. | Making of cocoon. | Pupal period. | | Leaving fruit. | Pupation. | Emergence of moth. | Making of cocoon. | Pupal period. |
| 1 | July 6 | July 9 | July 22 | 3 | 13 | 69 | .......... | July 23 | Aug. 5 | ........ | 13 |
| 2 | ...do.... | July 10 | July 26 | 4 | 16 | 70 | July 14 | ...do.... | Aug. 6 | 9 | 14 |
| 3 | ...do.... | ...do.... | July 23 | 4 | 15 | 71 | .......... | ...do.... | Aug. 7 | ........ | 15 |
| 4 | ...do.... | ...do.... | ...do.... | 4 | 13 | 72 | July 14 | Aug. 1 | Aug. 14 | 18 | 13 |
| 5 | ...do.... | ...do.... | July 25 | 4 | 15 | 73 | ...do.... | ...do.... | Aug. 15 | 18 | 14 |
| 6 | ...do.... | ...do.... | July 23 | 4 | 13 | 74 | July 15 | July 21 | Aug. 5 | 6 | 15 |
| 7 | ...do.... | ...do.... | July 26 | 4 | 16 | 75 | July 16 | July 24 | Aug. 7 | 8 | 14 |
| 8 | ...do.... | ...do.... | July 25 | 4 | 15 | 76 | .......... | ...do.... | ...do.... | ........ | 14 |
| 9 | ...do.... | ...do.... | July 24 | 4 | 14 | 77 | July 17 | July 21 | Aug. 5 | 4 | 15 |
| 10 | ...do.... | ...do.... | ...do.... | 4 | 14 | 78 | ...do.... | ...do.... | ...do.... | 4 | 15 |
| 11 | ...do.... | ...do.... | July 23 | 4 | 13 | 79 | ...do.... | July 23 | Aug. 6 | 6 | 14 |
| 12 | ...do.... | ...do.... | ...do.... | 4 | 13 | 80 | ...do.... | ...do.... | Aug. 7 | 6 | 15 |
| 13 | ...do.... | ...do.... | ...do.... | 4 | 13 | 81 | ...do.... | ...do.... | Aug. 8 | 6 | 16 |
| 14 | ...do.... | ...do.... | July 26 | 4 | 16 | 82 | ...do.... | July 24 | Aug. 3 | 7 | 10 |
| 15 | ...do.... | ...do.... | ...do.... | 4 | 16 | 83 | ...do.... | July 25 | Aug. 7 | 8 | 13 |
| 16 | ...do.... | ...do.... | July 28 | 4 | 18 | 84 | ...do.... | July 26 | ...do.... | 9 | 12 |
| 17 | ...do.... | ...do.... | July 27 | 4 | 17 | 85 | ...do.... | July 27 | Aug. 8 | 10 | 12 |
| 18 | ...do.... | July 11 | ...do.... | 5 | 16 | 86 | ...do.... | July 28 | Aug. 9 | 11 | 12 |
| 19 | ...do.... | ...do.... | ...do.... | 5 | 16 | 87 | ...do.... | ...do.... | Aug. 10 | 11 | 13 |
| 20 | ...do.... | ...do.... | July 26 | 5 | 15 | 88 | July 18 | July 24 | Aug. 7 | 6 | 14 |
| 21 | ...do.... | ...do.... | Aug. 1 | 5 | 21 | 89 | ...do.... | ...do.... | ...do.... | 6 | 14 |
| 22 | ...do.... | ...do.... | July 27 | 5 | 16 | 90 | ...do.... | July 25 | Aug. 6 | 7 | 12 |
| 23 | ...do.... | ...do.... | July 26 | 5 | 15 | 91 | ...do.... | ...do.... | Aug. 7 | 7 | 13 |
| 24 | ...do.... | ...do.... | ...do.... | 5 | 15 | 92 | ...do.... | ...do.... | ...do.... | 7 | 13 |
| 25 | ...do.... | ...do.... | July 27 | 5 | 16 | 93 | ...do.... | ...do.... | ...do.... | 7 | 13 |
| 26 | ...do.... | ...do.... | ...do.... | 5 | 16 | 94 | ...do.... | July 26 | ...do.... | 8 | 12 |
| 27 | ...do.... | ...do.... | July 28 | 5 | 17 | 95 | ...do.... | ...do.... | ...do.... | 8 | 12 |
| 28 | ...do.... | ...do.... | July 26 | 5 | 15 | 96 | ...do.... | ...do.... | ...do.... | 8 | 12 |
| 29 | ...do.... | July 12 | July 28 | 6 | 16 | 97 | ...do.... | ...do.... | ...do.... | 8 | 12 |
| 30 | ...do.... | July 14 | July 27 | 8 | 13 | 98 | ...do.... | ...do.... | ...do.... | 8 | 12 |
| 31 | ...do.... | ...do.... | July 30 | 8 | 16 | 99 | ...do.... | ...do.... | ...do.... | 8 | 12 |
| 32 | ...do.... | July 17 | Aug. 4 | 11 | 18 | 100 | ...do.... | ...do.... | Aug. 8 | 8 | 13 |
| 33 | July 9 | July 14 | July 30 | 5 | 16 | 101 | ...do.... | ...do.... | ...do.... | 8 | 13 |
| 34 | ...do.... | ...do.... | July 29 | 5 | 15 | 102 | ...do.... | ...do.... | ...do.... | 8 | 13 |
| 35 | ...do.... | ...do.... | July 31 | 5 | 17 | 103 | ...do.... | July 27 | Aug. 7 | 9 | 11 |
| 36 | ...do.... | ...do.... | July 29 | 5 | 15 | 104 | ...do.... | ...do.... | Aug. 8 | 9 | 12 |
| 37 | ...do.... | ...do.... | July 30 | 5 | 16 | 105 | ...do.... | ...do.... | ...do.... | 9 | 12 |
| 38 | ...do.... | ...do.... | July 29 | 5 | 15 | 106 | ...do.... | ...do.... | ...do.... | 9 | 12 |
| 39 | ...do.... | ...do.... | ...do.... | 5 | 15 | 107 | ...do.... | ...do.... | ...do.... | 9 | 12 |
| 40 | ...do.... | ...do.... | July 30 | 5 | 16 | 108 | ...do.... | ...do.... | ...do.... | 9 | 12 |
| 41 | ...do.... | July 15 | July 31 | 6 | 16 | 109 | ...do.... | ...do.... | Aug. 10 | 9 | 14 |
| 42 | ...do.... | ...do.... | ...do.... | 6 | 16 | 110 | ...do.... | ...do.... | Aug. 11 | 9 | 15 |
| 43 | ...do.... | ...do.... | ...do.... | 6 | 16 | 111 | ...do.... | July 28 | Aug. 7 | 10 | 10 |
| 44 | ...do.... | July 17 | Aug. 2 | 8 | 16 | 112 | ...do.... | ...do.... | Aug. 9 | 10 | 12 |
| 45 | July 12 | ...do.... | July 31 | 5 | 14 | 113 | ...do.... | ...do.... | ...do.... | 10 | 12 |
| 46 | ...do.... | July 18 | Aug. 1 | 6 | 14 | 114 | ...do.... | ...do.... | ...do.... | 10 | 12 |
| 47 | ...do.... | ...do.... | Aug. 2 | 6 | 15 | 115 | ...do.... | July 29 | Aug. 8 | 11 | 10 |
| 48 | ...do.... | ...do.... | ...do.... | 6 | 15 | 116 | ...do.... | ...do.... | Aug. 9 | 11 | 11 |
| 49 | ...do.... | ...do.... | ...do.... | 6 | 15 | 117 | ...do.... | ...do.... | Aug. 10 | 11 | 12 |
| 50 | ...do.... | ...do.... | Aug. 3 | 6 | 16 | 118 | ...do.... | ...do.... | ...do.... | 11 | 12 |
| 51 | ...do.... | ...do.... | ...do.... | 6 | 16 | 119 | July 19 | July 27 | Aug. 8 | 8 | 12 |
| 52 | ...do.... | ...do.... | Aug. 4 | 6 | 17 | 120 | ...do.... | .......... | Aug. 5 | 13 | ....... |
| 53 | ...do.... | July 19 | Aug. 2 | 7 | 14 | 121 | July 20 | July 29 | Aug. 9 | 9 | 11 |
| 54 | .......... | ...do.... | Aug. 3 | ........ | 15 | 122 | July 21 | July 30 | ...do.... | 9 | 10 |
| 55 | July 12 | ...do.... | ...do.... | 7 | 15 | 123 | ...do.... | Aug. 2 | Aug. 14 | 12 | 12 |
| 56 | ...do.... | ...do.... | ...do.... | 7 | 15 | 124 | ...do.... | Aug. 6 | Aug. 18 | 16 | 12 |
| 57 | ...do.... | ...do.... | ...do.... | 7 | 15 | 125 | July 23 | July 31 | Aug. 12 | 8 | 12 |
| 58 | ...do.... | ...do.... | Aug. 4 | 7 | 16 | 126 | ...do.... | ...do.... | ...do.... | 8 | 12 |
| 59 | .......... | July 20 | Aug. 3 | ........ | 14 | 127 | ...do.... | ...do.... | Aug. 18 | 8 | 18 |
| 60 | July 12 | ...do.... | Aug. 4 | 8 | 15 | 128 | ...do.... | Aug. 8 | Aug. 14 | 16 | 6 |
| 61 | .......... | ...do.... | ...do.... | ........ | 15 | 129 | July 24 | Aug. 1 | Aug. 15 | 8 | 16 |
| 62 | .......... | ...do.... | ...do.... | ........ | 15 | 130 | July 25 | Aug. 2 | Aug. 16 | 8 | 14 |
| 63 | July 12 | ...do.... | Aug. 5 | 8 | 16 | 131 | July 27 | Aug. 1 | Aug. 14 | 5 | 13 |
| 64 | .......... | July 21 | Aug. 4 | ........ | 14 | 132 | July 29 | Aug. 6 | Aug. 22 | 8 | 16 |
| 65 | July 12 | ...do.... | Aug. 5 | 9 | 15 | | | | | | |
| 66 | .......... | ...do.... | ...do.... | ........ | 15 | Average | | | | 7.2 | 14.0 |
| 67 | July 12 | July 23 | Aug. 5 | 11 | 13 | Maximum | | | | 18 | 21 |
| 68 | .......... | ...do.... | ...do.... | ........ | 13 | Minimum | | | | 3 | 6 |

### FIRST BROOD OF PUPÆ OR SUMMER PUPÆ.

*Time of pupation.*—The time of pupation as represented in figure 20 has been determined on the basis that the time and rate of emergence of the moths must be in close relation and in direct proportion to the time and rate of pupation. Observations on pupation in the rearing cages extended from July 6 to August 8. In the field, however, the pupation period was longer. From the records of emergence of moths we find that the earliest pupæ must have appeared about June 30 and the last pupæ about August 24.

*Length of pupal stage.*—In the course of rearing work two separate tests on the length of the pupal stage have been made. One of these (Tables XLVIII and XLIX) includes primarily observations on the pupal stage; the other (Table LV) contains observations on the life cycle of the insect. The results of Table XLVIII, including 132 insects, show that the period varied from 6 to 21 days, with an average of 14 days. The results from the life cycle series (Tables LV and LVI), covering 75 observations, showed a variation of 11 to 24 days, and an average of 15.18 days.

Table XLIX.—*Length of pupal stage of the summer brood, Douglas, Mich., 1911; summary of Table XLVIII.*

| Number of observations. | Days making cocoon. | Number of observations. | Days of pupal period. | Number of observations. | Days making cocoon. | Number of observations. | Days of pupal period. |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 13 | 9 | 17 | 14 | 2 | 16 |
| 18 | 4 | 1 | 6 | 28 | 15 | 2 | 18 |
| 21 | 5 | 4 | 10 | 5 | 10 | 24 | 16 |
| 17 | 6 | 3 | 11 | 8 | 11 | 4 | 17 |
| 10 | 7 | 25 | 12 | 1 | 12 | 3 | 18 |
| 23 | 8 | 21 | 13 | 1 | 13 | 1 | 21 |

Table L.—*Time of emergence of moths of the summer brood from band records, Douglas, Mich., 1911.*

| Date of emergence. | Band records. | | | | | Total. | Date of emergence. | Band records. | | | | | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Douglas. | Lake Shore. | Pentwater. | New Richmond. | Benton Harbor. | | | Douglas. | Lake Shore. | Pentwater. | New Richmond. | Benton Harbor. | |
| July 8 | ...... | ...... | ...... | 2 | 3 | 5 | Aug. 13 | 3 | 10 | 6 | ...... | 3 | 22 |
| July 9 | ...... | ...... | ...... | ...... | 4 | 4 | Aug. 14 | 6 | 13 | 19 | 3 | 12 | 53 |
| July 10 | 1 | 2 | 4 | 3 | 21 | 33 | Aug. 15 | 1 | 5 | 10 | ...... | 1 | 17 |
| July 11 | 1 | 2 | 8 | 5 | 16 | 32 | Aug. 16 | ...... | 6 | 8 | 1 | 1 | 16 |
| July 12 | ...... | 3 | 4 | ...... | ...... | 7 | Aug. 17 | ...... | 8 | 6 | 1 | 3 | 18 |
| July 13 | 2 | 2 | 16 | 1 | 17 | 38 | Aug. 18 | 1 | 12 | 9 | ...... | ...... | 22 |
| July 14 | ...... | 2 | 9 | ...... | 19 | 30 | Aug. 19 | ...... | 5 | 3 | ...... | ...... | 8 |
| July 15 | ...... | 2 | 4 | ...... | 9 | 15 | Aug. 20 | ...... | ...... | 5 | ...... | ...... | 5 |
| July 16 | ...... | 1 | 2 | ...... | 10 | 13 | Aug. 21 | 3 | 8 | 2 | 4 | 4 | 21 |
| July 17 | ...... | 1 | 3 | ...... | 11 | 15 | Aug. 22 | 2 | 5 | 5 | 1 | 2 | 15 |
| July 18 | ...... | 4 | 3 | 1 | 10 | 18 | Aug. 23 | ...... | 3 | 2 | ...... | 1 | 6 |
| July 19 | ...... | 2 | 5 | ...... | 11 | 18 | Aug. 24 | 2 | 1 | 3 | ...... | 1 | 7 |
| July 20 | ...... | 2 | 1 | 1 | 8 | 12 | Aug. 25 | ...... | 4 | 2 | ...... | ...... | 6 |
| July 21 | ...... | 1 | 2 | ...... | 10 | 13 | Aug. 26 | 2 | 3 | 2 | 1 | ...... | 8 |
| July 22 | 1 | 1 | 1 | 1 | 11 | 15 | Aug. 27 | ...... | 2 | 1 | 1 | ...... | 4 |
| July 23 | ...... | 6 | 2 | 2 | 8 | 18 | Aug. 28 | 1 | 2 | 2 | ...... | ...... | 5 |
| July 24 | ...... | 2 | 2 | 1 | 8 | 13 | Aug. 29 | ...... | 2 | 2 | ...... | ...... | 4 |
| July 25 | ...... | 2 | 2 | 2 | 10 | 16 | Aug. 30 | ...... | 1 | 1 | ...... | 1 | 3 |
| July 26 | ...... | 9 | ...... | 3 | 9 | 21 | Aug. 31 | 1 | ...... | 1 | 3 | ...... | 5 |
| July 27 | ...... | 6 | ...... | 2 | 7 | 15 | Sept. 1 | 2 | 1 | ...... | ...... | ...... | 3 |
| July 28 | 1 | 4 | 2 | ...... | 7 | 14 | Sept. 2 | 1 | 1 | 2 | 1 | 4 | 9 |
| July 29 | ...... | 4 | 2 | 2 | 11 | 19 | Sept. 3 | 2 | 1 | ...... | ...... | 3 | 6 |
| July 30 | 2 | 5 | 2 | 1 | 10 | 20 | Sept. 4 | ...... | 2 | ...... | ...... | 1 | 3 |
| July 31 | 4 | 4 | 4 | 4 | 19 | 35 | Sept. 5 | ...... | 1 | 2 | 1 | 1 | 5 |
| Aug. 1 | 1 | 2 | 13 | 4 | 19 | 39 | Sept. 6 | ...... | ...... | 1 | ...... | ...... | 1 |
| Aug. 2 | ...... | 5 | 7 | ...... | 4 | 16 | Sept. 7 | ...... | 1 | 1 | 1 | ...... | 3 |
| Aug. 3 | 2 | 4 | 15 | 2 | 12 | 35 | Sept. 8 | ...... | 1 | 1 | ...... | ...... | 2 |
| Aug. 4 | ...... | 4 | 12 | ...... | 13 | 29 | Sept. 9 | ...... | 1 | ...... | ...... | ...... | 1 |
| Aug. 5 | 10 | 10 | 17 | 2 | 13 | 52 | Sept. 10 | ...... | ...... | ...... | ...... | 1 | 1 |
| Aug. 6 | 8 | 4 | 12 | 2 | 14 | 40 | Sept. 11 | ...... | ...... | 1 | ...... | ...... | 1 |
| Aug. 7 | 12 | 15 | 35 | 11 | 17 | 90 | Sept. 16 | ...... | ...... | ...... | ...... | 1 | 1 |
| Aug. 8 | 4 | 14 | 16 | 7 | 19 | 60 | Sept. 17 | ...... | ...... | ...... | ...... | 1 | 1 |
| Aug. 9 | 6 | 19 | 20 | 2 | 13 | 60 | Sept. 18 | ...... | ...... | ...... | ...... | 1 | 1 |
| Aug. 10 | 5 | 22 | 23 | 5 | 12 | 67 | | | | | | | |
| Aug. 11 | 1 | 9 | 20 | 3 | 6 | 39 | Total . | 91 | 287 | 372 | 89 | 440 | 1,279 |
| Aug. 12 | 3 | 13 | 7 | ...... | 7 | 30 | | | | | | | |

### FIRST BROOD OF MOTHS OR SUMMER MOTHS.

*Time of emergence.*—The records for emergence of summer moths are given in Table L, covering 1,279 observations from five separate band records. The codling-moth larvæ from the band records at Benton Harbor, New Richmond, Douglas, Lake Shore, and Pentwater were all sent to the station at Douglas, and the observations on the date of issue of the moths were all made there. The curve of figure 16 represents the total emergence of moths and is based upon the records of Table L. It will be noted that there existed a striking similarity in the rate of emergence and that the time of emergence was practically the same for the different band records. This may be due to the peculiar climatic conditions of 1911, when the spring opened up uniformly over the entire fruit belt—a rather unusual occurrence. It may also be that during the middle of the summer the seasonal conditions became equalized over the different sections, and produced a corresponding equalizing tendency upon the development of the codling moth.

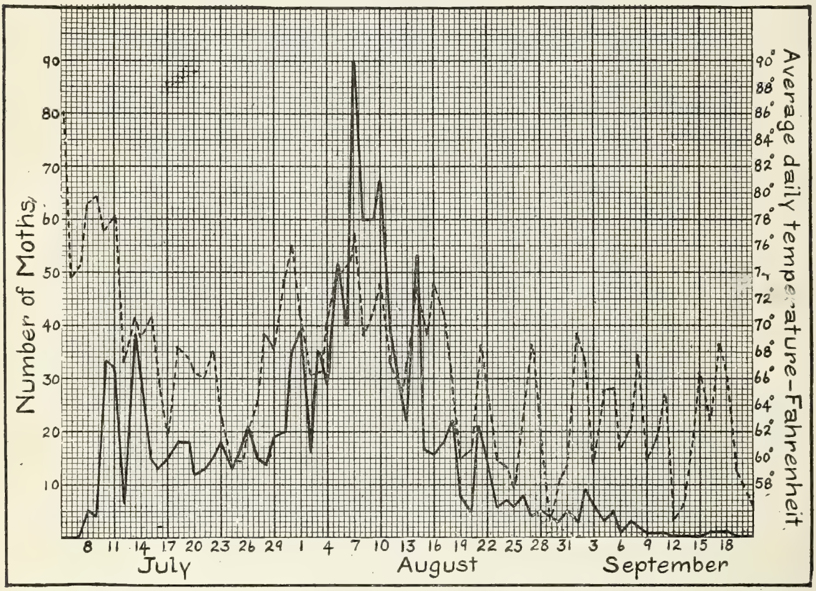

FIG. 16.—Emergence curve of moths of the summer brood in 1911, at Douglas, Mich. (Original.)

The emergence records for the summer moths are remarkable both in respect to time and rate of appearance of the moths. The earliest moths issued July 8, which emergence was 21 days earlier then that of the more normal season of 1910. During the early part of the emergence period, from July 10 to July 14, moths appeared in abundance. During the later half of July, however, they were less numerous, while during the first half of August they were again very abundant, reaching a maximum August 7. During the remaining part of the emergence period, which extended to September 18, comparatively few moths appeared.

TABLE LI.—*Oviposition of moths of the summer brood in captivity, Douglas, Mich., 1911.*

| Number of cage. | Number of moths per cage. | Date of— | | | Days— | | |
|---|---|---|---|---|---|---|---|
| | | Emergence of moths. | First oviposition. | Last oviposition. | Before oviposition. | Of oviposition. | From time of emergence to last oviposition. |
| 1 | 29 | July 10 | July 14 | July 20 | 4 | 7 | 10 |
| 2 | 24 | July 11 | ...do..... | July 24 | 3 | 11 | 13 |
| 3 | 10 | July 12 | ...do..... | Aug. 1 | 2 | 19 | 20 |
| 4 | 29 | July 13 | July 16 | July 27 | 3 | 12 | 14 |
| 5 | 26 | July 14 | July 23 | July 24 | 9 | 2 | 10 |
| 6 | 15 | July 15 | July 18 | July 26 | 3 | 9 | 11 |
| 7 | 10 | July 16 | July 20 | July 28 | 4 | 9 | 12 |
| 8 | 14 | July 20 | July 26 | July 31 | 6 | 6 | 11 |
| 9 | 15 | July 21 | July 28 | Aug. 5 | 7 | 9 | 15 |
| 10 | 16 | July 22 | ...do..... | July 30 | 6 | 3 | 8 |
| 11 | 15 | July 23 | ...do..... | Aug. 4 | 5 | 8 | 12 |
| 12 | 13 | July 25 | July 27 | ...do..... | 2 | 9 | 10 |
| 13 | 25 | July 26 | July 31 | Aug. 1 | 5 | 2 | 6 |
| 14 | 11 | July 27 | ...do.... | Aug. 2 | 4 | 3 | 6 |
| 15 | 14 | July 28 | Aug. 1 | Aug. 7 | 4 | 7 | 10 |
| 16 | 17 | July 29 | July 31 | Aug. 14 | 2 | 15 | 16 |
| 17 | 18 | July 30 | Aug. 1 | Aug. 10 | 2 | 10 | 11 |
| 18 | 36 | July 31 | Aug. 2 | Aug. 18 | 2 | 17 | 18 |
| 19 | 37 | Aug. 1 | Aug. 6 | Aug. 7 | 5 | 2 | 6 |
| 20 | 15 | Aug. 2 | Aug. 5 | Aug. 9 | 3 | 5 | 7 |
| 21 | 38 | Aug. 3 | Aug. 6 | Aug. 15 | 3 | 10 | 12 |
| 22 | 34 | Aug. 4 | ...do..... | Aug. 16 | 2 | 11 | 12 |
| 23 | 54 | Aug. 5 | Aug. 7 | Aug. 12 | 2 | 6 | 7 |
| 24 | 35 | Aug. 6 | Aug. 8 | Aug. 13 | 2 | 6 | 7 |
| 25 | 88 | Aug. 7 | Aug. 9 | Aug. 16 | 2 | 8 | 9 |
| 26 | 55 | Aug. 9 | Aug. 11 | Aug. 17 | 2 | 7 | 8 |
| 27 | 54 | Aug. 10 | Aug. 12 | Aug. 31 | 2 | 20 | 21 |
| 28 | 27 | Aug. 12 | Aug. 13 | Aug. 23 | 1 | 11 | 11 |
| 29 | 19 | Aug. 13 | Aug. 17 | Aug. 21 | 4 | 5 | 8 |
| 30 | 47 | Aug. 14 | Aug. 16 | Aug. 25 | 2 | 10 | 11 |
| 31 | 21 | Aug. 16 | Aug. 18 | Aug. 28 | 2 | 11 | 12 |
| 32 | 16 | Aug. 17 | ...do..... | Sept. 3 | 1 | 17 | 17 |
| 33 | 27 | Aug. 18 | Aug. 21 | Aug. 28 | 3 | 8 | 10 |
| 34 | 23 | Aug. 21 | Aug. 22 | Sept. 14 | 1 | 24 | 24 |
| 35 | 15 | Aug. 22 | Aug. 25 | Sept. 3 | 3 | 10 | 12 |
| Average | | | | | 3.2 | 9.4 | 11.6 |
| Maximum | | | | | 9 | 24 | 24 |
| Minimum | | | | | 1 | 2 | 6 |

*Time of oviposition.*—Observations on egg deposition by the summer moths in captivity were made under conditions already described on page 14 for the spring brood. The results as presented in Table LI show that on an average the first eggs were laid 3 days after the time of emergence of the moths and that oviposition extended on an average to 9.4 days. Within the various cages considerable variation will be noted; in one instance the first eggs were obtained the following day after the emergence, in another instance the ninth day; in one cage the last eggs were deposited the sixth day, and in another cage the twenty-fourth day after the time of emergence of the moths.

On correlating the above observations with the time of emergence of the moths it will be found that the oviposition period extended from about July 11 to September 25. However, very few eggs were laid during September, and not all of these hatched. The great majority of eggs were deposited during August.

TABLE LII.—*Length of life of male and female moths of the first brood; summary of records of 1,019 individual moths.*

| Male. | | Female. | | Male. | | Female. | |
|---|---|---|---|---|---|---|---|
| Length of life. | Number of moths. | Length of life. | Number of moths. | Length of life. | Number of moths. | Length of life. | Number of moths. |
| *Days.* | | *Days.* | | *Days.* | | *Days.* | |
| 1 | 1 | 1 | 1 | 18 | 6 | 18 | 10 |
| 2 | 8 | 2 | 5 | 19 | 2 | 19 | 9 |
| 3 | 16 | 3 | 6 | 20 | 5 | 20 | 10 |
| 4 | 22 | 4 | 15 | 21 | 2 | 21 | 13 |
| 5 | 22 | 5 | 24 | 22 | 1 | 22 | 9 |
| 6 | 42 | 6 | 32 | 23 | 2 | 23 | 2 |
| 7 | 46 | 7 | 27 | 25 | 1 | 24 | 2 |
| 8 | 48 | 8 | 62 | 26 | 1 | 26 | 4 |
| 9 | 50 | 9 | 46 | 32 | 1 | 28 | 1 |
| 10 | 41 | 10 | 53 | .......... | .......... | 29 | 2 |
| 11 | 30 | 11 | 48 | .......... | .......... | 30 | 1 |
| 12 | 32 | 12 | 43 | .......... | .......... | 32 | 1 |
| 13 | 18 | 13 | 40 | .......... | .......... | 33 | 1 |
| 14 | 24 | 14 | 33 | .......... | .......... | 37 | 1 |
| 15 | 12 | 15 | 26 | | | | |
| 16 | 11 | 16 | 22 | Total.. | 456 | .......... | 563 |
| 17 | 12 | 17 | 14 | | | | |

TABLE LIII.—*Longevity of male and female moths of the first brood; summary of Table LII.*

| Observations. | Life of male moths. | Life of female moths. |
|---|---|---|
| | *Days.* | *Days.* |
| Average | 9.57 | 11.49 |
| Maximum | 32 | 37 |
| Minimum | 1 | 1 |

*Length of life of male and female moths.*—A summary of observations from 1,910 individual moths is recorded in Table LII. The condition under which the moths were kept has already been referred to on page 39. As observed for the previous brood, the longevity of the males was shorter than that for the females. On an average the males lived 9.57 days and the females 11.49 days; the maximum length of life for the males was 32 days and for the females 37 days.

It is of interest to note that the results obtained by the writer at North East, Pa., in 1909,[1] are almost identical with those given above; the average length of life for the males being 9.79 days and for the females 11.47 days.

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[1] Bul. 80, Pt. VI, Bur. Ent., U. S. Dept. Agr., p. 91, 1910.

The females were found to be more numerous than the males, which was also observed in the spring brood of moths.

*Length of life cycle of the first generation.*—In Table LIV are brought together the average results from observations for the separate stages of the first generation. These data show that on an average there elapsed 53.59 days from the time of appearance of eggs of the first brood to the time of appearance of eggs of the second brood. Comparing these results with those of the complete life-cycle series (Tables LV–LVI), there will be found a difference of results of less than one day. In the life-cycle tests 75 individual insects were under observation from the time of the deposition of the eggs to the time of emergence of the moths that resulted from these eggs.

TABLE LIV.—*Summary of results from experiments on the separate stages of the first generation of the codling moth in 1911.*

| Life cycle of first generation. | Number of days. | | |
|---|---|---|---|
| | Average. | Maximum. | Minimum. |
| Incubation of eggs | 7.94 | 10 | 4 |
| Feeding period of larvæ | 21.25 | 29 | 15 |
| Making of cocoons | 7.2 | 18 | 3 |
| Pupal stages | 14.0 | 21 | 6 |
| Time before egg deposition | 3.2 | 9 | 1 |
| Total | 53.59 | 87 | 29 |

TABLE LV.—*Life cycle of the first generation of the codling moth, as observed by rearing at Douglas, Mich., in 1911.*

| No. of observation. | Date of— | | | | | Days for— | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Egg deposition. | Hatching. | Larva leaving the fruit. | Pupation. | Emergence of moth. | Hatching. | Feeding. | Making of cocoon. | Pupal period. | Total life cycle. |
| 1 | June 1 | June 10 | July 4 | July 9 | July 22 | 9 | 24 | 5 | 13 | 51 |
| 2 | do | do | do | July 11 | | 9 | 24 | 7 | | |
| 3 | do | do | do | do | July 27 | 9 | 24 | 7 | 16 | 56 |
| 4 | June 3 | June 11 | do | July 8 | | 8 | 23 | 4 | | |
| 5 | June 5 | June 13 | July 8 | July 26 | Aug. 8 | 8 | 25 | 18 | 13 | 64 |
| 6 | do | do | July 9 | July 14 | July 31 | 8 | 26 | 5 | 17 | 56 |
| [1] 7 | June 6 | June 15 | July 6 | July 9 | July 23 | 9 | 21 | 3 | 14 | 47 |
| [1] 8 | do | do | July 8 | July 11 | July 26 | 9 | 23 | 3 | 15 | 50 |
| [1] 9 | do | do | do | do | do | 9 | 23 | 3 | 15 | 50 |
| [1] 10 | do | do | do | do | do | 9 | 23 | 3 | 15 | 50 |
| [1] 11 | do | do | do | July 18 | Aug. 3 | 9 | 23 | 10 | 16 | 58 |
| [1] 12 | do | do | July 9 | July 16 | Aug. 1 | 9 | 24 | 7 | 16 | 56 |
| [1] 13 | do | do | | | [2] July 31 | 9 | | | | 55 |
| [1] 14 | do | do | | | [2] July 25 | 9 | | | | 49 |
| [1] 15 | June 8 | June 18 | July 8 | July 11 | | 10 | 20 | 3 | | |
| [1] 16 | do | do | July 12 | July 24 | Aug. 7 | 10 | 24 | 12 | 14 | 60 |
| [1] 17 | June 9 | do | July 8 | July 12 | July 31 | 9 | 20 | 4 | 19 | 52 |
| [1] 18 | do | do | July 9 | July 13 | July 30 | 9 | 21 | 4 | 17 | 51 |
| [1] 19 | do | do | do | July 18 | Aug. 3 | 9 | 21 | 9 | 16 | 55 |
| [1] 20 | do | do | July 12 | July 14 | July 31 | 9 | 24 | 2 | 17 | 52 |
| 21 | June 10 | June 19 | July 8 | July 13 | July 29 | 9 | 19 | 5 | 16 | 49 |
| 22 | do | do | July 13 | July 23 | | 9 | 24 | 10 | | |
| 23 | do | do | July 14 | do | | 9 | 25 | 9 | | |
| 24 | do | do | do | July 21 | Aug. 5 | 9 | 25 | 7 | 15 | 56 |
| 25 | do | do | July 15 | July 22 | | 9 | 26 | 7 | | |
| 26 | June 11 | June 20 | July 6 | July 10 | July 23 | 9 | 16 | 4 | 13 | 42 |

[1] Bagged fruit; average feeding, 20.9 days.

[2] Pupated in fruit; average feeding, 21.4 days.

TABLE LV.—*Life cycle of the first generation of the codling moth, as observed by rearing at Douglas, Mich., in 1911*—Continued.

| No. of observation. | Date of— | | | | | Days for— | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Egg deposition. | Hatching. | Larva leaving the fruit. | Pupation. | Emergence of moth. | Hatching. | Feeding. | Making of cocoon. | Pupal period. | Total life cycle. |
| 27 | June 11 | June 20 | July 7 | July 12 | .......... | 9 | 17 | 5 | ........ | ........ |
| 28 | ...do..... | ...do..... | ...do..... | ...do..... | July 29 | 9 | 17 | 5 | 17 | 48 |
| 29 | ...do..... | ...do..... | July 9 | July 13 | July 30 | 9 | 19 | 4 | 17 | 49 |
| 30 | ...do..... | ...do..... | July 13 | July 18 | Aug. 4 | 9 | 23 | 5 | 17 | 54 |
| 31 | ...do..... | ...do..... | ...do..... | July 20 | Aug. 5 | 9 | 23 | 7 | 16 | 55 |
| [1] 32 | ...do..... | ...do..... | July 7 | July 12 | July 28 | 9 | 17 | 5 | 16 | 47 |
| [1] 33 | ...do..... | ...do..... | July 9 | July 13 | July 31 | 9 | 19 | 4 | 18 | 50 |
| [1] 34 | ...do..... | ...do..... | ...do..... | July 12 | July 28 | 9 | 19 | 3 | 16 | 47 |
| [1] 35 | ...do..... | ...do..... | July 13 | July 19 | Aug. 4 | 9 | 23 | 6 | 16 | 54 |
| 36 | June 12 | June 21 | July 6 | July 9 | July 22 | 9 | 15 | 3 | 13 | 40 |
| 37 | ...do..... | ...do..... | July 8 | July 14 | July 31 | 9 | 17 | 6 | 17 | 49 |
| 38 | ...do..... | ...do..... | July 10 | July 16 | Aug. 1 | 9 | 19 | 6 | 16 | 50 |
| 39 | ...do..... | ...do..... | ...do..... | July 15 | July 31 | 9 | 19 | 5 | 16 | 49 |
| 40 | ...do..... | ...do..... | ...do..... | July 16 | Aug. 2 | 9 | 19 | 6 | 17 | 51 |
| 41 | ...do..... | ...do..... | July 11 | ...do..... | Aug. 9 | 9 | 20 | 5 | 24 | 58 |
| 42 | ...do..... | ...do..... | ...do..... | July 15 | July 31 | 9 | 20 | 4 | 16 | 49 |
| [1] 43 | ...do..... | ...do..... | July 9 | ...do..... | ...do..... | 9 | 18 | 6 | 16 | 49 |
| [1] 44 | ...do..... | ...do..... | July 15 | .......... | Aug. 8 | 9 | 24 | ........ | ........ | 57 |
| [1] 45 | ...do..... | ...do..... | .......... | .......... | [2] July 31 | 9 | ........ | ........ | ........ | 49 |
| 46 | June 13 | June 22 | July 11 | July 20 | Aug. 4 | 9 | 19 | 9 | 15 | 52 |
| 47 | ...do..... | ...do..... | ...do..... | July 18 | ...do..... | 9 | 19 | 7 | 17 | 52 |
| 48 | ...do..... | ...do..... | July 12 | ...do..... | Aug. 3 | 9 | 20 | 6 | 16 | 51 |
| 49 | ...do..... | ...do..... | ...do..... | July 21 | Aug. 5 | 9 | 20 | 9 | 15 | 53 |
| [1] 50 | June 14 | ...do..... | July 10 | July 15 | July 31 | 8 | 18 | 5 | 16 | 47 |
| [1] 51 | ...do..... | ...do..... | July 11 | July 16 | Aug. 1 | 8 | 19 | 5 | 16 | 48 |
| [1] 52 | ...do..... | ...do..... | ...do..... | July 17 | ...do..... | 8 | 19 | 6 | 15 | 48 |
| [1] 53 | ...do..... | ...do..... | July 21 | July 29 | Aug. 10 | 8 | 29 | 8 | 12 | 57 |
| [1] 54 | ...do..... | ...do..... | .......... | .......... | [2] Aug. 1 | 8 | ........ | ........ | ........ | 48 |
| 55 | June 15 | June 23 | July 9 | July 14 | July 30 | 8 | 16 | 5 | 16 | 45 |
| 56 | ...do..... | ...do..... | July 12 | July 18 | .......... | 8 | 19 | 6 | ........ | ........ |
| 57 | ...do..... | ...do..... | July 18 | July 26 | Aug. 8 | 8 | 25 | 8 | 13 | 54 |
| [1] 58 | June 16 | ...do..... | July 12 | July 17 | Aug. 2 | 7 | 19 | 5 | 16 | 47 |
| [1] 59 | ...do..... | ...do..... | ...do..... | July 19 | Aug. 4 | 7 | 19 | 7 | 16 | 49 |
| [1] 60 | ...do..... | ...do..... | July 13 | July 18 | Aug. 1 | 7 | 20 | 5 | 14 | 46 |
| 61 | June 18 | June 24 | July 12 | July 27 | .......... | 6 | 18 | 15 | ........ | ........ |
| 62 | ...do..... | ...do..... | July 17 | July 30 | Aug. 10 | 6 | 23 | 13 | 11 | 53 |
| 63 | ...do..... | ...do..... | July 18 | ...do..... | .......... | 6 | 24 | 12 | ........ | ........ |
| 64 | ...do..... | ...do..... | July 20 | July 28 | Aug. 9 | 6 | 26 | 8 | 12 | 52 |
| 65 | ...do..... | ...do..... | July 23 | July 29 | Aug. 10 | 6 | 29 | 6 | 12 | 53 |
| 66 | June 19 | June 26 | July 15 | July 26 | Aug. 9 | 7 | 19 | 11 | 14 | 51 |
| 67 | June 20 | June 27 | July 12 | July 20 | Aug. 5 | 7 | 15 | 8 | 16 | 46 |
| 68 | ...do..... | ...do..... | July 24 | July 29 | Aug. 10 | 7 | 27 | 5 | 12 | 51 |
| 69 | ...do..... | ...do..... | .......... | Aug. 4 | Aug. 18 | 7 | ........ | ........ | 14 | 59 |
| [1] 70 | ...do..... | ...do..... | July 14 | July 21 | Aug. 5 | 7 | 17 | 7 | 15 | 46 |
| [1] 71 | ...do..... | ...do..... | ...do..... | July 23 | Aug. 6 | 7 | 17 | 9 | 14 | 47 |
| [1] 72 | ...do..... | ...do..... | July 20 | July 29 | Aug. 10 | 7 | 23 | 9 | 12 | 51 |
| 73 | June 26 | July 3 | July 28 | Aug. 3 | Aug. 15 | 7 | 25 | 6 | 12 | 50 |
| 74 | June 27 | July 4 | ...do..... | ...do..... | ...do..... | 7 | 24 | 6 | 12 | 49 |
| 75 | ...do..... | ...do..... | ...do..... | Aug. 6 | Aug. 19 | 7 | 24 | 9 | 13 | 53 |

[1] Bagged fruit; average feeding, 20.9 days.

[2] Pupated in fruit; average feeding, 21.4 days.

TABLE LVI.—*Length of the life cycle of the first generation; summary of Table LV.*

| Observations. | Days for— | | | | |
|---|---|---|---|---|---|
| | Hatching. | Feeding. | Making of cocoon. | Pupal period. | Total life cycle. |
| Average.................... | 8.33 | 21.25 | 6.54 | 15.18 | 51.10 |
| Maximum.................... | 10 | 29 | 18 | 24 | 64 |
| Minimum.................... | 6 | 15 | 2 | 11 | 42 |

It is of interest to note the extent of variation in the length of the life cycle of the first generation. The figures of Table LIV show a maximum length of time for the entire life cycle of 87 days and a minimum of 29 days, or a range of variation of 58 days. From the above results it becomes evident that reliable conclusions can not be made from a limited number of observations no matter how accurate the records may be; they only represent the results under limited conditions. Such conclusions may readily become extremely misleading when used as a basis for timing spray applications. By using the average length of the life cycle of 51 days it will be found that three broods of the codling moth could have existed in the Michigan fruit belt in 1911. Or should we, on the other hand, choose to use the records for the minimum length of the life cycle we could on that basis account for the existence of a fourth brood of the codling moth. Our observations, however, only show evidence of two broods, since out of several thousand larvæ of the second brood not a single insect pupated in 1911.

## THE SECOND GENERATION.

### SECOND BROOD OF EGGS.

*Time of incubation.*—Eggs of the second brood occurred in the field for about three months. During this long period the different eggs were often subjected to strikingly different climatic conditions, which resulted in an unusual degree of variation in the time of incubation. In Table LVII are included the records for 110 observations. The time of incubation here varied from 6 to 16 days and averaged 9.35 days for the whole period. During the latter part of July and first half of August, when the greatest abundance of eggs was found, the time of incubation varied from 6 to 8 days. As for the first brood of eggs, observations were also made on the embryological development of the second brood of eggs, namely, the time of appearance of the "red ring" and the "black spot." The summarized results in Table LIX show that the red ring appeared on an average within 3 days after egg deposition and the black spot 2 days previous to hatching. A number of eggs deposited during the middle part of September failed to hatch, mostly due to the prevailing low temperature. The fact that the red ring had already appeared in these eggs proved them to be fertile.

All of the eggs used in these tests were laid in the rearing cages, and there were 4,643 eggs under observation as listed in Table LVII.

TABLE LVII.—*Length of incubation of the second brood of eggs, and average temperature during incubation, Douglas, Mich., 1911.*

| No. of observation. | Number of eggs. | Date of— | | | | Duration of— | | | Average mean temperature. |
|---|---|---|---|---|---|---|---|---|---|
| | | Egg deposition. | Appearance of red ring. | Appearance of black spot. | Hatching. | Red ring. | Black spot. | Incubation. | |
| | | | | | | *Days.* | *Days.* | *Days.* | *°F.* |
| 1 | 18 | July 14 | July 18 | July 20 | July 22 | 4 | 6 | 8 | 66.96 |
| 2 | 23 | July 15 | July 19 | July 21 | July 23 | 4 | 6 | 8 | 66.83 |
| 3 | 35 | July 17 | July 21 | July 23 | July 24 | 4 | 6 | 7 | 66.00 |
| 4 | 59 | July 18 | July 23 | July 25 | July 28 | 5 | 7 | 10 | 64.60 |
| 5 | 67 | July 19 | July 24 | July 27 | ...do.... | 5 | 8 | 9 | 64.18 |
| 6 | 15 | ...do.... | ...do.... | ...do.... | July 29 | 5 | 8 | 10 | 64.67 |
| 7 | 64 | July 20 | July 26 | July 28 | ...do.... | 6 | 8 | 9 | 64.35 |
| 8 | 8 | ...do.... | ...do.... | ...do.... | July 30 | 6 | 8 | 10 | 64.73 |
| 9 | 5 | July 22 | July 27 | July 29 | July 31 | 5 | 7 | 9 | 65.41 |
| 10 | 8 | ...do.... | ...do.... | ...do.... | Aug. 1 | 5 | 7 | 10 | 66.47 |
| 11 | 27 | July 23 | July 28 | July 30 | July 31 | 5 | 7 | 8 | 65.09 |
| 12 | 25 | ...do.... | ...do.... | July 31 | Aug. 1 | 5 | 8 | 9 | 66.30 |
| 13 | 15 | July 24 | July 29 | ...do.... | ...do.... | 5 | 7 | 8 | 66.63 |
| 14 | 17 | July 26 | July 31 | Aug. 1 | Aug. 2 | 5 | 6 | 7 | 69.20 |
| 15 | 12 | July 27 | ...do.... | ...do.... | ...do.... | 4 | 5 | 6 | 70.33 |
| 16 | 4 | ...do.... | ...do.... | ...do.... | Aug. 3 | 4 | 5 | 7 | 69.76 |
| 17 | 12 | July 28 | July 30 | Aug. 2 | ...do.... | 2 | 5 | 6 | 70.70 |
| 18 | 4 | ...do.... | ...do.... | ...do.... | Aug. 4 | 2 | 5 | 7 | 70.08 |
| 19 | 14 | July 29 | Aug. 2 | Aug. 3 | ...do.... | 4 | 5 | 6 | 70.23 |
| 20 | 3 | ...do.... | ...do.... | ...do.... | Aug. 5 | 4 | 5 | 7 | 70.22 |
| 21 | 172 | July 30 | ...do.... | Aug. 4 | ...do.... | 3 | 5 | 6 | 70.55 |
| 22 | 12 | ...do.... | ...do.... | ...do.... | Aug. 6 | 3 | 5 | 7 | 71.00 |
| 23 | 95 | July 31 | ...do.... | Aug. 5 | ...do.... | 2 | 5 | 6 | 70.54 |
| 24 | 30 | ...do.... | ...do.... | ...do.... | Aug. 7 | 2 | 5 | 7 | 71.07 |
| 25 | 46 | Aug. 1 | Aug. 3 | ...do.... | ...do.... | 2 | 4 | 6 | 70.25 |
| 26 | 22 | ...do.... | ...do.... | Aug. 6 | Aug. 8 | 2 | 5 | 7 | 71.22 |
| 27 | 72 | Aug. 2 | Aug. 4 | Aug. 7 | ...do.... | 2 | 5 | 6 | 71.29 |
| 28 | 4 | ...do.... | ...do.... | ...do.... | Aug. 9 | 2 | 5 | 7 | 71.01 |
| 29 | 40 | Aug. 3 | Aug. 5 | Aug. 8 | ...do.... | 2 | 5 | 6 | 71.81 |
| 30 | 8 | ...do.... | Aug. 6 | ...do.... | Aug. 10 | 3 | 5 | 7 | 71.74 |
| 31 | 30 | Aug. 4 | ...do.... | Aug. 9 | Aug. 11 | 2 | 5 | 7 | 72.61 |
| 32 | 111 | Aug. 5 | Aug. 8 | Aug. 10 | ...do.... | 3 | 5 | 6 | 73.01 |
| 33 | 17 | ...do.... | Aug. 7 | ...do.... | Aug. 12 | 2 | 5 | 7 | 72.20 |
| 34 | 146 | Aug. 6 | Aug. 8 | Aug. 11 | ...do.... | 2 | 5 | 6 | 71.95 |
| 35 | 60 | ...do.... | ...do.... | ...do.... | Aug. 13 | 2 | 5 | 7 | 71.00 |
| 36 | 188 | Aug. 7 | ...do.... | Aug. 12 | Aug. 14 | 1 | 5 | 7 | 69.97 |
| 37 | 18 | ...do.... | ...do.... | Aug. 13 | Aug. 15 | 1 | 6 | 8 | 70.39 |
| 38 | 309 | Aug. 8 | Aug. 11 | Aug. 14 | ...do.... | 3 | 6 | 7 | 66.59 |
| 39 | 3 | ...do.... | ...do.... | ...do.... | Aug. 16 | 3 | 6 | 8 | 69.47 |
| 40 | 3 | Aug. 9 | Aug. 12 | ...do.... | Aug. 15 | 3 | 5 | 6 | 69.47 |
| 41 | 99 | ...do.... | ...do.... | ...do.... | Aug. 16 | 3 | 5 | 7 | 69.49 |
| 42 | 13 | ...do.... | ...do.... | Aug. 15 | Aug. 17 | 3 | 6 | 8 | 69.96 |
| 43 | 298 | Aug. 10 | Aug. 13 | ...do.... | ...do.... | 3 | 5 | 7 | 69.86 |
| 44 | 4 | ...do.... | ...do.... | ...do.... | Aug. 18 | 3 | 5 | 8 | 69.99 |
| 45 | 310 | Aug. 11 | ...do.... | Aug. 16 | Aug. 17 | 2 | 5 | 6 | 69.33 |
| 46 | 130 | ...do.... | Aug. 14 | ...do.... | Aug. 18 | 3 | 5 | 7 | 69.56 |
| 47 | 37 | ...do.... | ...do.... | Aug. 17 | Aug. 19 | 3 | 6 | 8 | 69.15 |
| 48 | 128 | Aug. 12 | Aug. 15 | ...do.... | Aug. 18 | 3 | 5 | 6 | 69.92 |
| 49 | 37 | ...do.... | ...do.... | ...do.... | Aug. 19 | 3 | 5 | 7 | 69.40 |
| 50 | 130 | Aug. 13 | Aug. 16 | Aug. 18 | Aug. 20 | 3 | 6 | 7 | 68.65 |
| 51 | 102 | ...do.... | ...do.... | ...do.... | Aug. 21 | 3 | 6 | 8 | 67.68 |
| 52 | 87 | Aug. 14 | Aug. 17 | Aug. 19 | ...do.... | 3 | 5 | 7 | 67.77 |
| 53 | 58 | ...do.... | ...do.... | Aug. 20 | Aug. 22 | 3 | 6 | 8 | 67.86 |
| 54 | 198 | Aug. 15 | ...do.... | Aug. 21 | ...do.... | 2 | 6 | 7 | 67.07 |
| 55 | 68 | ...do.... | ...do.... | ...do.... | Aug. 23 | 2 | 6 | 8 | 66.85 |
| 56 | 8 | ...do.... | ...do.... | ...do.... | Aug. 24 | 2 | 6 | 9 | 66.08 |
| 57 | 8 | ...do.... | ...do.... | Aug. 22 | Aug. 25 | 2 | 7 | 10 | 65.40 |
| 58 | 37 | Aug. 16 | Aug. 19 | Aug. 23 | Aug. 24 | 3 | 7 | 8 | 65.63 |
| 59 | 17 | ...do.... | ...do.... | ...do.... | Aug. 25 | 3 | 7 | 9 | 66.04 |
| 60 | 27 | ...do.... | Aug. 20 | Aug. 24 | Aug. 26 | 4 | 8 | 10 | 64.23 |
| 61 | 8 | ...do.... | ...do.... | ...do.... | Aug. 27 | 4 | 8 | 11 | 64.16 |
| 62 | 21 | Aug. 17 | Aug. 19 | ...do.... | Aug. 26 | 2 | 7 | 9 | 63.22 |
| 63 | 39 | ...do.... | Aug. 20 | Aug. 25 | Aug. 27 | 3 | 8 | 10 | 63.24 |
| 64 | 40 | ...do.... | ...do.... | ...do.... | Aug. 28 | 3 | 8 | 11 | 63.72 |
| 65 | 206 | Aug. 18 | ...do.... | Aug. 26 | ...do.... | 2 | 8 | 10 | 62.99 |
| 66 | 18 | ...do.... | ...do.... | Aug. 27 | Aug. 29 | 2 | 9 | 11 | 62.97 |
| 67 | 26 | Aug. 19 | Aug. 21 | Aug. 28 | Aug. 30 | 2 | 9 | 11 | 62.00 |
| 68 | 4 | ...do.... | ...do.... | ...do.... | Aug. 31 | 2 | 9 | 12 | 61.69 |
| 69 | 119 | Aug. 21 | Aug. 23 | Aug. 30 | Sept. 1 | 2 | 9 | 11 | 61.71 |
| 70 | 28 | ...do.... | ...do.... | ...do.... | Sept. 2 | 2 | 9 | 12 | 62.36 |
| 71 | 32 | Aug. 22 | Aug. 25 | ...do.... | Sept. 1 | 3 | 8 | 10 | 61.03 |

TABLE LVII.—*Length of incubation of the second brood of eggs, and average temperature during incubation, Douglas, Mich., 1911*—Continued.

| No. of observation. | Number of eggs. | Date of— | | | | Duration of— | | | Average mean temperature. |
|---|---|---|---|---|---|---|---|---|---|
| | | Egg deposition. | Appearance of red ring. | Appearance of black spot. | Hatching. | Red ring. | Black spot. | Incubation. | |
| | | | | | | *Days.* | *Days.* | *Days.* | °*F.* |
| 72 | 80 | Aug. 22 | Aug. 25 | Aug. 30 | Sept. 2 | 3 | 8 | 11 | 61.81 |
| 73 | 50 | Aug. 24 | Aug. 26 | Sept. 2 | Sept. 4 | 2 | 9 | 11 | 61.96 |
| 74 | 3 | ...do.... | ...do.... | ...do.... | Sept. 5 | 2 | 9 | 12 | 62.23 |
| 75 | 21 | Aug. 26 | Aug. 30 | ...do.... | ...do.... | 4 | 7 | 10 | 62.95 |
| 76 | 46 | Aug. 27 | Aug. 31 | Sept. 3 | ...do.... | 4 | 7 | 9 | 62.90 |
| 77 | 16 | ...do.... | ...do.... | ...do.... | Sept. 6 | 4 | 7 | 10 | 63.17 |
| 78 | 26 | Aug. 28 | ...do.... | Sept. 5 | ...do.... | 3 | 8 | 9 | 62.59 |
| 79 | 8 | ...do.... | ...do.... | ...do.... | Sept. 7 | 3 | 8 | 10 | 62.41 |
| 80 | 12 | ...do.... | Sept. 1 | Sept. 6 | Sept. 8 | 4 | 9 | 11 | 62.39 |
| 81 | 3 | ...do.... | ...do.... | ...do.... | Sept. 9 | 4 | 9 | 12 | 62.84 |
| 82 | 8 | Aug. 30 | Sept. 2 | Sept. 8 | ...do.... | 3 | 9 | 10 | 63.58 |
| 83 | 5 | ...do.... | ...do.... | ...do.... | Sept. 10 | 3 | 9 | 11 | 63.27 |
| 84 | 6 | Aug. 31 | Sept. 3 | Sept. 9 | ...do.... | 3 | 9 | 10 | 63.77 |
| 85 | 9 | ...do.... | ...do.... | ...do.... | Sept. 11 | 3 | 9 | 11 | 63.60 |
| 86 | 10 | Sept. 2 | Sept. 6 | Sept. 12 | Sept. 15 | 4 | 10 | 13 | 62.14 |
| 87 | 40 | Sept. 8 | Sept. 11 | Sept. 16 | Sept. 18 | 3 | 8 | 10 | 62.46 |
| 88 | 20 | ...do.... | ...do.... | ...do.... | Sept. 19 | 3 | 8 | 11 | 62.85 |
| 89 | 5 | Sept. 9 | Sept. 12 | Sept. 17 | ...do.... | 3 | 8 | 10 | 62.34 |
| 90 | 3 | ...do.... | ...do.... | Sept. 18 | Sept. 20 | 3 | 9 | 11 | 62.06 |
| 91 | 1 | ...do.... | ...do.... | ...do.... | Sept. 25 | 3 | 9 | 16 | 61.09 |
| 92 | 1 | Sept. 10 | Sept. 13 | Sept. 19 | Sept. 21 | 3 | 9 | 11 | 61.86 |
| 93 | 2 | ...do.... | ...do.... | ...do.... | Sept. 22 | 3 | 9 | 12 | 61.39 |
| 94 | 1 | ...do.... | ...do.... | Sept. 20 | Sept. 24 | 3 | 10 | 14 | 61.09 |
| 95 | 29 | Sept. 11 | Sept. 15 | ...do.... | Sept. 22 | 4 | 9 | 11 | 61.35 |
| 96 | 16 | ...do.... | ...do.... | ...do.... | Sept. 23 | 4 | 9 | 12 | 60.92 |
| 97 | 1 | ...do.... | Sept. 16 | Sept. 21 | Sept. 24 | 5 | 10 | 13 | 61.03 |
| 98 | 1 | ...do.... | ...do.... | Sept. 22 | Sept. 25 | 5 | 11 | 14 | 61.11 |
| 99 | 3 | Sept. 12 | ...do.... | ...do.... | Sept. 24 | 4 | 10 | 12 | 60.71 |
| 100 | 1 | ...do.... | ...do.... | ...do.... | Sept. 25 | 4 | 10 | 13 | 60.81 |
| 101 | 19 | Sept. 13 | Sept. 17 | ...do.... | Sept. 24 | 4 | 9 | 11 | 61.19 |
| 102 | 6 | ...do.... | ...do.... | ...do.... | Sept. 25 | 4 | 9 | 12 | 61.27 |
| 103 | 4 | ...do.... | ...do.... | Sept. 23 | Sept. 26 | 4 | 10 | 13 | 60.93 |
| 104 | 1 | ...do.... | ...do.... | ...do.... | Sept. 27 | 4 | 10 | 14 | 60.43 |
| 105 | 1 | ...do.... | ...do.... | ...do.... | Sept. 28 | 4 | 10 | 15 | 60.47 |
| 106 | 5 | Sept. 14 | ...do.... | Sept. 22 | Sept. 24 | 3 | 8 | 10 | 61.68 |
| 107 | 1 | ...do.... | ...do.... | Sept. 23 | Sept. 28 | 3 | 9 | 14 | 60.76 |
| 108 | 7 | Sept. 17 | Sept. 25 | Sept. 27 | Sept. 29 | 8 | 10 | 12 | 59.60 |
| 109 | 1 | ...do.... | ...do.... | ...do.... | Oct. 1 | 8 | 10 | 14 | 58.55 |
| 110 | 2 | ...do.... | ...do.... | ...do.... | Oct. 3 | 8 | 10 | 16 | 57.80 |

TABLE LVIII.—*Length of incubation of second-brood eggs laid in rearing cages, Douglas, Mich., 1911; summary of Table LVII.*

| Appearance of red ring. | | Appearance of black spot. | | Total incubation period. | |
|---|---|---|---|---|---|
| Number of days. | Number of observations. | Number of days. | Number of observations. | Number of days. | Number of observations. |
| 1 | 2 | 4 | 1 | 6 | 13 |
| 2 | 27 | 5 | 30 | 7 | 22 |
| 3 | 41 | 6 | 15 | 8 | 13 |
| 4 | 24 | 7 | 12 | 9 | 9 |
| 5 | 11 | 8 | 18 | 10 | 17 |
| 6 | 2 | 9 | 22 | 11 | 15 |
| 8 | 3 | 10 | 11 | 12 | 9 |
| .......... | .......... | 11 | 1 | 13 | 4 |
| .......... | .......... | .......... | .......... | 14 | 5 |
| .......... | .......... | .......... | .......... | 15 | 1 |
| .......... | .......... | .......... | .......... | 16 | 2 |

TABLE LIX.—*Length of incubation of second-brood eggs laid in rearing cages, Douglas, Mich., 1911; summary of Tables LVII and LVIII.*

| Observations. | Number of days— | | |
|---|---|---|---|
| | For appearance of red ring. | For appearance of black spot. | For incubation. |
| Average | 3.33 | 7.19 | 9.35 |
| Maximum | 8 | 11 | 16 |
| Minimum | 1 | 4 | 6 |

*Effect of temperature upon the time of incubation.*—The general effect of the temperature upon the time of incubation of the codling moth eggs has already been considered on page 44 and the results for the second brood of eggs have there been given in the diagram (fig. 15) together with those for the first brood. In Table LVII the average daily temperature is given for the 110 separate observations. These temperature records have further been summarized to averages for the respective days of incubation as given in Table LX. The range in variation of average degrees of temperature for the different days is shown in the same table in the columns of maximum and minimum.

TABLE LX.—*Average mean temperature during incubation of second-brood eggs, Douglas, Mich., 1911; summary of Table LVII.*

| Days of incubation. | Number of observations. | Average mean temperature. | | |
|---|---|---|---|---|
| | | Average. | Maximum. | Minimum. |
| | | ° *F.* | ° *F.* | ° *F.* |
| 6 | 13 | 70.72 | 73.01 | 69.33 |
| 7 | 22 | 69.79 | 72.61 | 66.00 |
| 8 | 13 | 67.88 | 70.39 | 65.09 |
| 9 | 9 | 64.56 | 66.30 | 62.59 |
| 10 | 17 | 63.51 | 66.47 | 61.03 |
| 11 | 15 | 62.46 | 64.16 | 61.19 |
| 12 | 9 | 61.45 | 62.84 | 59.60 |
| 13 | 4 | 61.23 | 62.14 | 60.81 |
| 14 | 5 | 60.39 | 61.11 | 58.55 |
| 15 | 1 | 60.47 | ........ | ........ |
| 16 | 2 | 59.44 | 61.09 | 57.80 |

## SECOND BROOD OF LARVÆ.

*Time of hatching.*—In the field the hatching period extended from July 18 to October 3. The great majority of larvæ hatched during the latter part of July and throughout August; during September only a few appeared. The period of hatching of larvæ of the second brood, extending over two months and a half, is very exceptional in comparison with the records for a normal season. During 1910 the period of hatching of eggs of the second brood was less than one month and a half.

TABLE LXI.—*Length of feeding period of second-brood larvæ, Douglas, Mich., 1911.*

| No. of observation. | Date of— | | Days of feeding. | No. of observation. | Date of— | | Days of feeding. | No. of observation. | Date of— | | Days of feeding. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hatching. | Leaving fruit. | | | Hatching. | Leaving fruit. | | | Hatching. | Leaving fruit. | |
| 1 | July 23 | Aug. 18 | 26 | 69 | Aug. 12 | Oct. 10 | 59 | 137 | Aug. 20 | Oct. 7 | 48 |
| 2 | ...do..... | Aug. 19 | 27 | 70 | ...do..... | Oct. 12 | 61 | 138 | ...do..... | ...do..... | 48 |
| 3 | July 24 | ...do..... | 26 | 71 | ...do..... | Oct. 20 | 69 | 139 | ...do..... | ...do..... | 48 |
| 4 | ...do..... | Aug. 21 | 28 | 72 | Aug. 15 | Sept. 4 | 20 | 140 | ...do..... | Oct. 8 | 49 |
| 5 | ...do..... | Aug. 28 | 35 | 73 | ...do..... | Sept. 6 | 22 | 141 | ...do..... | Oct. 11 | 52 |
| 6 | ...do..... | ...do..... | 35 | 74 | ...do..... | Sept. 17 | 33 | 142 | ...do..... | Oct. 13 | 54 |
| 7 | ...do..... | Sept. 5 | 43 | 75 | ...do..... | ...do..... | 33 | 143 | Aug. 21 | Sept. 21 | 31 |
| 8 | July 28 | Aug. 19 | 22 | 76 | ...do..... | Sept. 18 | 34 | 144 | ...do..... | Sept. 26 | 36 |
| 9 | ...do..... | ...do..... | 22 | 77 | ...do..... | Sept. 19 | 35 | 145 | ...do..... | ...do..... | 36 |
| 10 | ...do..... | Aug. 20 | 23 | 78 | ...do..... | Sept. 26 | 42 | 146 | ...do..... | Oct. 1 | 41 |
| 11 | ...do..... | Aug. 21 | 24 | 79 | ...do..... | Sept. 28 | 44 | 147 | ...do..... | Oct. 3 | 43 |
| 12 | ...do..... | ...do..... | 24 | 80 | ...do..... | ...do..... | 44 | 148 | ...do..... | Oct. 6 | 46 |
| 13 | ...do..... | ...do..... | 24 | 81 | ...do..... | Sept. 29 | 45 | 149 | ...do..... | Nov. 13 | 84 |
| 14 | ...do..... | Aug. 22 | 25 | 82 | Aug. 16 | Sept. 12 | 27 | 150 | Aug. 22 | Sept. 29 | 38 |
| 15 | ...do..... | Aug. 26 | 29 | 83 | ...do..... | Sept. 14 | 29 | 151 | ...do..... | ...do..... | 38 |
| 16 | ...do..... | Aug. 27 | 30 | 84 | ...do..... | ...do..... | 29 | 152 | ...do..... | ...do..... | 38 |
| 17 | ...do..... | Aug. 28 | 31 | 85 | ...do..... | Sept. 17 | 32 | 153 | ...do..... | Oct. 7 | 46 |
| 18 | ...do..... | ...do..... | 31 | 86 | ...do..... | ...do..... | 32 | 154 | ...do..... | Oct. 8 | 47 |
| 19 | ...do..... | Aug. 29 | 32 | 87 | ...do..... | ...do..... | 32 | 155 | ...do..... | Oct. 14 | 53 |
| 20 | ...do..... | Sept. 1 | 35 | 88 | ...do..... | Sept. 24 | 39 | 156 | ...do..... | Oct. 16 | 55 |
| 21 | ...do..... | Sept. 2 | 36 | 89 | ...do..... | Sept. 26 | 41 | 157 | Aug. 23 | Oct. 1 | 39 |
| 22 | ...do..... | ...do..... | 36 | 90 | ...do..... | Oct. 26 | 71 | 158 | ...do..... | Oct. 3 | 41 |
| 23 | ...do..... | Sept. 4 | 38 | 91 | Aug. 17 | Sept. 8 | 22 | 159 | ...do..... | Oct. 6 | 44 |
| 24 | July 29 | Aug. 21 | 23 | 92 | ...do..... | Sept. 15 | 29 | 160 | ...do..... | ...do..... | 44 |
| 25 | ...do..... | ...do..... | 23 | 93 | ...do..... | Sept. 17 | 31 | 161 | ...do..... | Oct. 16 | 54 |
| 26 | ...do..... | ...do..... | 23 | 94 | ...do..... | ...do..... | 31 | 162 | Aug. 24 | Sept. 29 | 36 |
| 27 | ...do..... | ...do..... | 23 | 95 | ...do..... | Sept. 19 | 33 | 163 | ...do..... | ...do..... | 36 |
| 28 | ...do..... | Aug. 24 | 26 | 96 | ...do..... | Sept. 22 | 36 | 164 | ...do..... | Oct. 3 | 40 |
| 29 | ...do..... | ...do..... | 26 | 97 | ...do..... | ...do..... | 36 | 165 | ...do..... | ...do..... | 40 |
| 30 | ...do..... | Aug. 29 | 31 | 98 | ...do..... | ...do..... | 36 | 166 | Aug. 25 | Sept. 28 | 34 |
| 31 | July 31 | Aug. 28 | 28 | 99 | ...do..... | ...do..... | 36 | 167 | ...do..... | ...do..... | 34 |
| 32 | ...do..... | ...do..... | 28 | 100 | ...do..... | Sept. 23 | 37 | 168 | ...do..... | Oct. 7 | 43 |
| 33 | ...do..... | Aug. 31 | 31 | 101 | ...do..... | ...do..... | 37 | 169 | ...do..... | Oct. 20 | 56 |
| 34 | ...do..... | Sept. 7 | 38 | 102 | ...do..... | ...do..... | 37 | 170 | Aug. 26 | Sept. 28 | 33 |
| 35 | Aug. 4 | Aug. 28 | 24 | 103 | ...do..... | Sept. 24 | 38 | 171 | ...do..... | Oct. 6 | 41 |
| 36 | ...do..... | Aug. 29 | 25 | 104 | ...do..... | ...do..... | 38 | 172 | ...do..... | Oct. 15 | 50 |
| 37 | ...do..... | Sept. 7 | 34 | 105 | ...do..... | Sept. 26 | 40 | 173 | ...do..... | Oct. 16 | 51 |
| 38 | ...do..... | Sept. 9 | 36 | 106 | ...do..... | ...do..... | 40 | 174 | ...do..... | ...do..... | 51 |
| 39 | Aug. 6 | Sept. 4 | 29 | 107 | ...do..... | ...do..... | 40 | 175 | ...do..... | Oct. 17 | 52 |
| 40 | ...do..... | ...do..... | 29 | 108 | ...do..... | ...do..... | 40 | 176 | ...do..... | Oct. 20 | 55 |
| 41 | ...do..... | ...do..... | 29 | 109 | ...do..... | ...do..... | 40 | 177 | ...do..... | Oct. 23 | 58 |
| 42 | ...do..... | Sept. 11 | 36 | 110 | ...do..... | Sept. 29 | 43 | 178 | Aug. 27 | Oct. 8 | 42 |
| 43 | ...do..... | Sept. 16 | 41 | 111 | ...do..... | ...do..... | 43 | 179 | ...do..... | Oct. 9 | 43 |
| 44 | ...do..... | Sept. 26 | 51 | 112 | ...do..... | ...do..... | 43 | 180 | ...do..... | Oct. 15 | 49 |
| 45 | Aug. 7 | Aug. 28 | 21 | 113 | ...do..... | Oct. 1 | 45 | 181 | ...do..... | Oct. 16 | 50 |
| 46 | ...do..... | Sept. 4 | 28 | 114 | ...do..... | ...do..... | 45 | 182 | Aug. 28 | Oct. 14 | 47 |
| 47 | Aug. 11 | ...do..... | 24 | 115 | ...do..... | ...do..... | 45 | 183 | ...do..... | Oct. 17 | 50 |
| 48 | ...do..... | Sept. 11 | 31 | 116 | ...do..... | ...do..... | 45 | 184 | ...do..... | Oct. 20 | 53 |
| 40 | ...do..... | ...do..... | 31 | 117 | ...do..... | ...do..... | 45 | 185 | ...do..... | ...do..... | 53 |
| 50 | ...do..... | Sept. 12 | 32 | 118 | ...do..... | Oct. 6 | 50 | 186 | Sept. 1 | Oct. 14 | 43 |
| 51 | ...do..... | Sept. 14 | 34 | 119 | ...do..... | Oct. 14 | 58 | 187 | Sept. 2 | Oct. 26 | 54 |
| 52 | ...do..... | Sept. 16 | 36 | 120 | ...do..... | Oct. 18 | 62 | 188 | Sept. 4 | Oct. 19 | 45 |
| 53 | ...do..... | Sept. 17 | 37 | 121 | ...do..... | Oct. 20 | 64 | 189 | ...do..... | Oct. 20 | 46 |
| 54 | ...do..... | ...do..... | 37 | 122 | ...do..... | Nov. 1 | 76 | 190 | ...do..... | Oct. 23 | 49 |
| 55 | ...do..... | Sept. 19 | 39 | 123 | Aug. 18 | Sept. 19 | 32 | 191 | ...do..... | Nov. 13 | 70 |
| 56 | ...do..... | Sept. 26 | 46 | 124 | ...do..... | Sept. 28 | 41 | 192 | ...do..... | ...do..... | 70 |
| 57 | ...do..... | Oct. 10 | 60 | 125 | ...do..... | Sept. 29 | 42 | 193 | ...do..... | ...do..... | 70 |
| 58 | ...do..... | Oct. 11 | 61 | 126 | ...do..... | Oct. 3 | 46 | 194 | Sept. 5 | ...do..... | 69 |
| 59 | Aug. 12 | Sept. 7 | 26 | 127 | ...do..... | Nov. 10 | 84 | 195 | Sept. 8 | Oct. 19 | 41 |
| 60 | ...do..... | Sept. 11 | 30 | 128 | Aug. 20 | Sept. 13 | 24 | 196 | Sept. 10 | Oct. 20 | 40 |
| 61 | ...do..... | Sept. 12 | 31 | 129 | ...do..... | Sept. 19 | 30 | 197 | ...do..... | Nov. 10 | 61 |
| 62 | ...do..... | Sept. 13 | 32 | 130 | ...do..... | Sept. 22 | 33 | 198 | ...do..... | Nov. 13 | 64 |
| 63 | ...do..... | Sept. 14 | 33 | 131 | ...do..... | ...do..... | 33 | 199 | Sept. 11 | Oct. 26 | 45 |
| 64 | ...do..... | Sept. 18 | 37 | 132 | ...do..... | ...do..... | 33 | | | | |
| 65 | ...do..... | ...do..... | 37 | 133 | ...do..... | ...do..... | 33 | | | | |
| 66 | ...do..... | Sept. 19 | 38 | 134 | ...do..... | Sept. 26 | 37 | Average | | | 40.03 |
| 67 | ...do..... | ...do..... | 38 | 135 | ...do..... | ...do..... | 37 | Maximum | | | 84 |
| 68 | ...do..... | Oct. 7 | 56 | 136 | ...do..... | Sept. 28 | 39 | Minimum | | | 20 |

TABLE LXII.—*Length of feeding period of second-brood larvæ, Douglas, Mich., 1911; summary of Table LXI.*

| Number of larvæ. | Days of feeding. | Number of larvæ. | Days of feeding. | Number of larvæ. | Days of feeding. | Number of larvæ. | Days of feeding. |
|---|---|---|---|---|---|---|---|
| 1 | 20 | 7 | 32 | 4 | 44 | 2 | 56 |
| 1 | 21 | 9 | 33 | 8 | 45 | 2 | 58 |
| 4 | 22 | 5 | 34 | 5 | 46 | 1 | 59 |
| 5 | 23 | 4 | 35 | 2 | 47 | 1 | 60 |
| 6 | 24 | 13 | 36 | 3 | 48 | 3 | 61 |
| 2 | 25 | 9 | 37 | 3 | 49 | 1 | 62 |
| 5 | 26 | 9 | 38 | 4 | 50 | 2 | 64 |
| 2 | 27 | 4 | 39 | 3 | 51 | 2 | 69 |
| 4 | 28 | 8 | 40 | 2 | 52 | 3 | 70 |
| 7 | 29 | 7 | 41 | 3 | 53 | 1 | 71 |
| 3 | 30 | 3 | 42 | 3 | 54 | 1 | 76 |
| 10 | 31 | 8 | 43 | 2 | 55 | 2 | 84 |

*Length of feeding period.*—The feeding period of the second-brood larvæ is considerably longer than has been recorded for the first-brood larvæ and is mainly the result of prevailing low temperatures during the late summer and the fall. The data from 199 observations (Table LXI) cover a long period of time extending from July 23, when the earliest larvæ hatched, to November 13, when the last larvæ left the fruit. There was a range in the length of the feeding period of from 20 to 84 days, with an average of 40 days.

*Time of maturity.*—In the rearing cages the first larvæ of the second brood left the fruit August 18, but these were not from the earliest eggs. Considering the time of feeding and the date of earliest oviposition, it is evident that in the field the first larvæ left the fruit about August 13. As noted from the band records, the last larvæ left the fruit November 13, which was also the last date of observation in the rearing cages.

## BAND RECORDS OF 1911.

During 1911 the band-record tests were extended to the following five localities: Benton Harbor, New Richmond, Douglas, lake shore (near Douglas), and Pentwater. The purpose of these tests in the widely separated sections of the Michigan fruit belt was to determine the possible existence of differences in the time of development of the codling moth.

The different band-record orchards were located respectively near Benton Harbor, 7 miles from the lake; at Douglas, on the grounds of the station 2 miles from the lake; at the lake shore, west of Douglas; and near Pentwater, about 7 miles from the lake. Most of the apple trees were old and none of them had been sprayed with poison. The number of trees and varieties of apples, so far as could be determined, were as follows: At Douglas, two trees Golden Russet, one Rhode Island Greening, one crab apple; at the lake shore, one King, two Canada Red, one Wealthy, one Astrachan, two winter varieties not determined; at New Richmond, two Baldwin, one Transcendent crab apple, one winter variety not determined; at Benton Harbor, one Golden Russet, one Canada Red, one crab apple, three fall varieties not determined; at Pentwater, six Ben Davis.

TABLE LXIII.—*Band records at Douglas, Mich., 1911.*

| No. of record. | Date of collecting. | Number of larvæ. | Emergence of moths, 1911. | Emergence of parasites, 1911. | Number of wintering larvæ. | No. of record. | Date of collecting. | Number of larvæ. | Emergence of moths, 1911. | Emergence of parasites, 1911. | Number of wintering larvæ. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | June 25 | 1 | ........ | ........ | 1 | 26 | Sept. 8 | 9 | ........ | ........ | 9 |
| 2 | June 28 | 2 | 2 | ........ | 0 | 27 | Sept. 11 | 13 | ........ | ........ | 13 |
| 3 | July 1 | 3 | 2 | ........ | 1 | 28 | Sept. 14 | 11 | ........ | ........ | 11 |
| 4 | July 4 | 0 | ........ | ........ | 0 | 29 | Sept. 17 | 20 | ........ | ........ | 20 |
| 5 | July 7 | 2 | 2 | ........ | 0 | 30 | Sept. 20 | 17 | ........ | ........ | 17 |
| 6 | July 10 | 15 | 5 | 1 | 9 | 31 | Sept. 23 | 19 | ........ | ........ | 19 |
| 7 | July 13 | 9 | 7 | ........ | 2 | 32 | Sept. 26 | 20 | ........ | ........ | 20 |
| 8 | July 16 | 21 | 14 | 6 | 1 | 33 | Sept. 29 | 27 | ........ | ........ | 27 |
| 9 | July 19 | 18 | 14 | ........ | 4 | 34 | Oct. 2 | 8 | ........ | ........ | 8 |
| 10 | July 22 | 21 | 20 | 1 | 0 | 35 | Oct. 5 | 10 | ........ | ........ | 10 |
| 11 | July 25 | 11 | 3 | 2 | 6 | 36 | Oct. 8 | 6 | ........ | ........ | 6 |
| 12 | July 28 | 13 | 5 | 4 | 4 | 37 | Oct. 11 | 16 | ........ | ........ | 16 |
| 13 | July 31 | 17 | 1 | 3 | 13 | 38 | Oct. 14 | 10 | ........ | ........ | 10 |
| 14 | Aug. 3 | 7 | 3 | 1 | 3 | 39 | Oct. 17 | 17 | ........ | ........ | 17 |
| 15 | Aug. 6 | 16 | 6 | ........ | 10 | 40 | Oct. 20 | 8 | ........ | ........ | 8 |
| 16 | Aug. 9 | 20 | 3 | 1 | 16 | 41 | Oct. 23 | 2 | ........ | ........ | 2 |
| 17 | Aug. 12 | 28 | 4 | ........ | 24 | 42 | Oct. 26 | 1 | ........ | ........ | 1 |
| 18 | Aug. 15 | 21 | ........ | ........ | 21 | 43 | Oct. 29 | 0 | ........ | ........ | 0 |
| 19 | Aug. 18 | 12 | ........ | ........ | 12 | 44 | Nov. 1 | 6 | ........ | ........ | 6 |
| 20 | Aug. 21 | 10 | ........ | ........ | 10 | 45 | Nov. 4 | 0 | ........ | ........ | 0 |
| 21 | Aug. 24 | 14 | ........ | ........ | 14 | 46 | Nov. 7 | 0 | ........ | ........ | 0 |
| 22 | Aug. 27 | 8 | ........ | ........ | 8 | 47 | Nov. 10 | 2 | ........ | ........ | 2 |
| 23 | Aug. 30 | 3 | ........ | ........ | 3 | 48 | Nov. 13 | 1 | ........ | ........ | 1 |
| 24 | Sept. 2 | 9 | ........ | ........ | 9 | | | | | | |
| 25 | Sept. 5 | 13 | ........ | ........ | 13 | Total...... | | 517 | 91 | 19 | 407 |

At Benton Harbor, New Richmond, and Pentwater the larvæ were collected respectively by Miss Clara Jakway, Mr. G. W. Tibbits, and Mr. S. J. Taylor, who sent the collected larvæ for each observation to the station at Douglas. Mailing cases (see fig. 17) containing small blocks of corrugated pasteboard were used and proved very satisfactory. Very few larvæ were injured during transportation, and not a single shipment was lost during the whole season. At the Douglas and lake shore orchards the larvæ were collected by the staff of the station.

TABLE LXIV.—*Band records of 1911 at Benton Harbor, Mich.; larvæ collected by Miss Clara Jakway.*

| No. of record. | Date of collecting. | Number of larvæ. | Emergence of moths, 1911. | Emergence of parasites, 1911. | Number of wintering larvæ. | No. of record. | Date of collecting. | Number of larvæ. | Emergence of moths, 1911. | Emergence of parasites, 1911. | Number of wintering larvæ. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | June 25 | 12 | 4 | 1 | 7 | 24 | Sept. 2 | 67 | ........ | ........ | 67 |
| 2 | June 28 | 58 | 37 | 2 | 19 | 25 | Sept. 5 | 53 | ........ | ........ | 53 |
| 3 | July 1 | 71 | 47 | 8 | 16 | 26 | Sept. 8 | 65 | ........ | ........ | 65 |
| 4 | July 4 | 120 | 66 | 9 | 45 | 27 | Sept. 11 | 37 | ........ | ........ | 37 |
| 5 | July 7 | 103 | 52 | 1 | 50 | 28 | Sept. 14 | 48 | ........ | ........ | 48 |
| 6 | July 10 | 94 | 43 | 7 | 44 | 29 | Sept. 17 | 32 | ........ | ........ | 32 |
| 7 | July 13 | 61 | 45 | 3 | 13 | 30 | Sept. 20 | 24 | ........ | ........ | 24 |
| 8 | July 16 | 46 | 28 | 2 | 16 | 31 | Sept. 23 | 15 | ........ | ........ | 15 |
| 9 | July 19 | 36 | 30 | ........ | 6 | 32 | Sept. 26 | 16 | ........ | ........ | 16 |
| 10 | July 22 | 37 | 27 | 2 | 8 | 33 | Sept. 29 | 8 | ........ | ........ | 8 |
| 11 | July 25 | 20 | 16 | ........ | 4 | 34 | Oct. 2 | 4 | ........ | ........ | 4 |
| 12 | July 28 | 19 | 15 | ........ | 4 | 35 | Oct. 5 | 4 | ........ | ........ | 4 |
| 13 | July 31 | 22 | 9 | ........ | 13 | 36 | Oct. 8 | 3 | ........ | ........ | 3 |
| 14 | Aug. 3 | 20 | 6 | ........ | 14 | 37 | Oct. 11 | 4 | ........ | ........ | 4 |
| 15 | Aug. 6 | 28 | 1 | ........ | 27 | 38 | Oct. 14 | 5 | ........ | ........ | 5 |
| 16 | Aug. 9 | 44 | ........ | ........ | 44 | 39 | Oct. 17 | 5 | ........ | ........ | 5 |
| 17 | Aug. 12 | 41 | 8 | ........ | 33 | 40 | Oct. 20 | 4 | ........ | ........ | 4 |
| 18 | Aug. 15 | 57 | 3 | ........ | 54 | 41 | Oct. 23 | 5 | ........ | ........ | 5 |
| 19 | Aug. 18 | 59 | 1 | ........ | 58 | 42 | Oct. 26 | 1 | ........ | ........ | 1 |
| 20 | Aug. 21 | 60 | 2 | ........ | 58 | 43 | Oct. 29 | 1 | ........ | ........ | 1 |
| 21 | Aug. 24 | 42 | ........ | ........ | 42 | | | | | | |
| 22 | Aug. 27 | 49 | 1 | ........ | 48 | Total...... | | 1,567 | 441 | 35 | 1,091 |
| 23 | Aug. 30 | 67 | ........ | ........ | 67 | | | | | | |

The results from the above band records are presented in Tables LXIII and LXVIII, in so far as same could be completed in 1911. The time of appearance of larvæ and their relative abundance in the respective localities have been graphically shown by curves in figures 18 and 19. It will be noted here that there is practically no difference in the time of appearance of the first larvæ in the five localities; nor is there any difference in the time of appearance of the earliest second-brood larvæ, so far as this could be determined. In accounting for this uniformity in time of maturity of larvæ it should be remembered that the seasonal conditions during 1911 were quite unusual. The spring opened up suddenly and uniformly over the entire fruit belt, and the prevailing high temperature must have started the development of the insects more or less at the same time in the different sections. During 1910, it will be recalled that in these localities a slight difference was observed in the time and rate of appearance of the first brood of larvæ and practically no difference in the time of appearance of the second brood of larvæ. We may deduce from these observations that the seasonal development may in years become more uniform in the different sections of the fruit belt than is generally the rule, and that these differences are more in evidence during the early spring than during the rest of the season, while at midsummer conditions are more or less uniform for the whole belt.

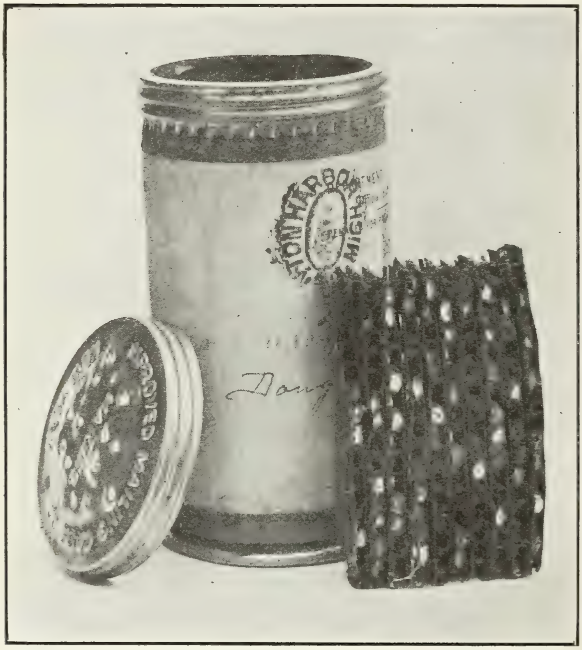

FIG. 17.—Mailing case used for shipping codling-moth larvæ. (Original.)

TABLE LXV.—*Band records at New Richmond, Mich., 1911; larvæ collected by G. W. Tibbits.*

| No. of record. | Date of collecting. | Number of larvæ. | Emergence of moths, 1911. | Emergence of parasites, 1911. | Number of wintering larvæ. | No. of record. | Date of collecting. | Number of larvæ. | Emergence of moths, 1911. | Emergence of parasites, 1911. | Number of wintering larvæ. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | June 25 | ........ | ........ | ........ | ........ | 24 | Sept. 2 | 7 | ........ | ........ | 7 |
| 2 | June 28 | 12 | 11 | ........ | 1 | 25 | Sept. 5 | 12 | ........ | ........ | 12 |
| 3 | July 1 | 8 | 2 | 1 | 5 | 26 | Sept. 8 | 8 | ........ | ........ | 8 |
| 4 | July 4 | 6 | 2 | ........ | 4 | 27 | Sept. 11 | 12 | ........ | ........ | 12 |
| 5 | July 7 | 17 | 10 | 1 | 6 | 28 | Sept. 14 | 12 | ........ | ........ | 12 |
| 6 | July 10 | 18 | 10 | 4 | 4 | 29 | Sept. 17 | 11 | ........ | ........ | 11 |
| 7 | July 13 | 17 | 5 | ........ | 12 | 30 | Sept. 20 | 14 | ........ | ........ | 14 |
| 8 | July 16 | 21 | 7 | ........ | 14 | 31 | Sept. 23 | 11 | ........ | ........ | 11 |
| 9 | July 19 | 16 | 10 | ........ | 6 | 32 | Sept. 26 | 16 | ........ | ........ | 16 |
| 10 | July 22 | 19 | 11 | 1 | 7 | 33 | Sept. 29 | 11 | ........ | ........ | 11 |
| 11 | July 25 | 17 | 5 | 1 | 11 | 34 | Oct. 2 | 4 | ........ | ........ | 4 |
| 12 | July 28 | 7 | 4 | 1 | 2 | 35 | Oct. 5 | 4 | ........ | ........ | 4 |
| 13 | July 31 | 5 | ........ | ........ | 5 | 36 | Oct. 8 | 3 | ........ | ........ | 3 |
| 14 | Aug. 3 | 9 | 5 | ........ | 4 | 37 | Oct. 11 | 5 | ........ | ........ | 5 |
| 15 | Aug. 6 | 14 | 2 | ........ | 12 | 38 | Oct. 14 | 4 | ........ | ........ | 4 |
| 16 | Aug. 9 | 11 | 3 | ........ | 8 | 39 | Oct. 17 | 4 | ........ | ........ | 4 |
| 17 | Aug. 12 | 20 | 3 | ........ | 17 | 40 | Oct. 20 | 1 | ........ | ........ | 1 |
| 18 | Aug. 15 | 14 | ........ | ........ | 14 | 41 | Oct. 23 | 3 | ........ | ........ | 3 |
| 19 | Aug. 18 | 12 | ........ | ........ | 12 | 42 | Oct. 26 | 1 | ........ | ........ | 1 |
| 20 | Aug. 21 | 12 | ........ | ........ | 12 | 43 | Oct. 29 | 1 | ........ | ........ | 1 |
| 21 | Aug. 24 | 13 | ........ | ........ | 13 | 44 | Nov. 1 | 1 | ........ | ........ | 1 |
| 22 | Aug. 27 | 10 | ........ | ........ | 10 | | | | | | |
| 23 | Aug. 30 | 11 | ........ | ........ | 11 | Total...... | | 434 | 90 | 9 | 335 |

The band-record curves in figures 18 and 19 are of further interest in that they show a marked irregularity in the rate of appearance of larvæ in the different orchards, and none of the curves show any natural demarcation between the two broods of larvæ which could be used as a basis to separate the two broods.

TABLE LXVI.—*Band records at the lake shore near Douglas, Mich., 1911.*

| No. of record. | Date of collecting. | Number of larvæ. | Emergence of moths, 1911. | Emergence of parasites, 1911. | Number of wintering larvæ. | No. of record. | Date of collecting. | Number of larvæ. | Emergence of moths, 1911. | Emergence of parasites, 1911. | Number of wintering larvæ. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | June 25 | 0 | ........ | ........ | 0 | 26 | Sept. 8 | 15 | ........ | ........ | 15 |
| 2 | June 28 | 12 | 4 | 5 | 3 | 27 | Sept. 11 | 25 | ........ | ........ | 25 |
| 3 | July 1 | 11 | 8 | 1 | 2 | 28 | Sept. 14 | 28 | ........ | ........ | 28 |
| 4 | July 4 | 14 | 12 | ........ | 2 | 29 | Sept. 17 | 28 | ........ | ........ | 28 |
| 5 | July 7 | 57 | 32 | ........ | 25 | 30 | Sept. 20 | 32 | ........ | ........ | 32 |
| 6 | July 10 | 23 | 12 | 1 | 10 | 31 | Sept. 23 | 26 | ........ | ........ | 26 |
| 7 | July 13 | 19 | 15 | ........ | 4 | 32 | Sept. 26 | 28 | ........ | ........ | 28 |
| 8 | July 16 | 23 | 17 | ........ | 6 | 33 | Sept. 29 | 17 | ........ | ........ | 17 |
| 9 | July 19 | 49 | 25 | ........ | 24 | 34 | Oct. 2 | 7 | ........ | ........ | 7 |
| 10 | July 22 | 48 | 38 | ........ | 10 | 35 | Oct. 5 | 11 | ........ | ........ | 11 |
| 11 | July 25 | 38 | 31 | 1 | 6 | 36 | Oct. 8 | 4 | ........ | ........ | 4 |
| 12 | July 28 | 43 | 22 | ........ | 21 | 37 | Oct. 11 | 12 | ........ | ........ | 12 |
| 13 | July 31 | 44 | 26 | ........ | 18 | 38 | Oct. 14 | 5 | ........ | ........ | 5 |
| 14 | Aug. 3 | 43 | 19 | 1 | 23 | 39 | Oct. 17 | 13 | ........ | ........ | 13 |
| 15 | Aug. 6 | 59 | 15 | ........ | 44 | 40 | Oct. 20 | 4 | ........ | ........ | 4 |
| 16 | Aug. 9 | 44 | 9 | ........ | 35 | 41 | Oct. 23 | 1 | ........ | ........ | 1 |
| 17 | Aug. 12 | 53 | ........ | ........ | 53 | 42 | Oct. 26 | 1 | ........ | ........ | 1 |
| 18 | Aug. 15 | 42 | 2 | ........ | 40 | 43 | Oct. 29 | 0 | ........ | ........ | 0 |
| 19 | Aug. 18 | 32 | ........ | ........ | 32 | 44 | Nov. 1 | 1 | ........ | ........ | 1 |
| 20 | Aug. 21 | 34 | ........ | ........ | 34 | 45 | Nov. 4 | 0 | ........ | ........ | 0 |
| 21 | Aug. 24 | 27 | ........ | ........ | 27 | 46 | Nov. 7 | 0 | ........ | ........ | 0 |
| 22 | Aug. 27 | 28 | ........ | ........ | 28 | 47 | Nov 10 | 2 | ........ | ........ | 2 |
| 23 | Aug. 30 | 32 | ........ | ........ | 32 | | | | | | |
| 24 | Sept. 2 | 44 | ........ | ........ | 44 | Total...... | | 1,125 | 287 | 9 | 829 |
| 25 | Sept. 5 | 46 | ........ | ........ | 46 | | | | | | |

Some of the band records might even become misleading were they not supplemented by observations from the rearing experiments. For instance the great drop in the curve of the Benton Harbor record (fig. 19) was due to the exposed condition of the apple trees and to severe storms during the latter half of July. Owing to the dropping of over half of the apple crop that resulted, a large number of larvæ failed to reach the bands, and many immature larvæ were materially delayed in their normal growth in apples on the ground. There is also to be noted a marked difference in the relative abundance of first-brood and second-brood larvæ in the different localities. Of the total number of larvæ of the Douglas band records 50 per cent were of the second brood, while of the Pentwater records only 31 per cent pertained to the second brood. For a comparison of the details of the results for the five band records reference is made to Table LXVIII.

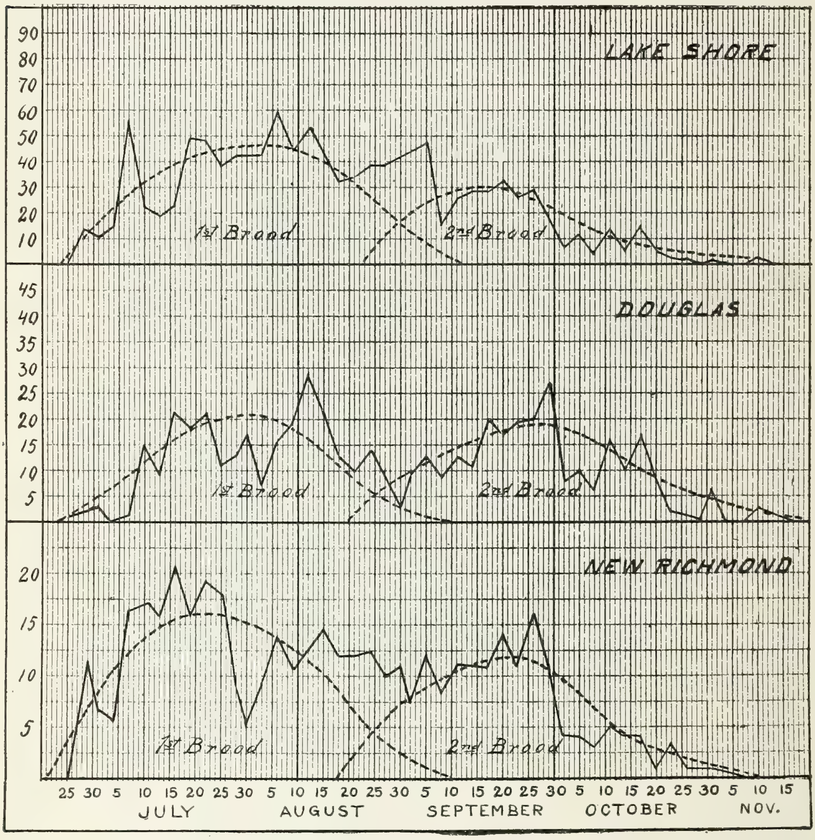

FIG. 18.—Curves made from band-record experiments in orchards at the lake shore near Douglas, at Douglas, and at New Richmond, Mich., 1911. (Original.)

TABLE LXVII.—*Band records of 1911, at Pentwater, Mich.; larvæ collected by S. J. Taylor.*

| No. of record. | Date of collecting. | Number of larvæ. | Emergence of moths, 1911. | Emergence of parasites, 1911. | Number of wintering larvæ. | No. of record. | Date of collecting. | Number of larvæ. | Emergence of moths, 1911. | Emergence of parasites, 1911. | Number of wintering larvæ. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | June 25 | 6 | 1 | ........ | 5 | 27 | Sept. 11 | 18 | ........ | ........ | 18 |
| 2 | June 28 | 10 | 5 | ........ | 5 | 28 | Sept. 14 | 12 | ........ | ........ | 12 |
| 3 | July 1 | 56 | 44 | 2 | 10 | 29 | Sept. 17 | 14 | ........ | ........ | 14 |
| 4 | July 4 | 24 | 9 | ........ | 15 | 30 | Sept. 20 | 16 | ........ | ........ | 16 |
| 5 | July 7 | 18 | 11 | ........ | 7 | 31 | Sept. 23 | 17 | ........ | ........ | 17 |
| 6 | July 10 | 17 | 4 | ........ | 13 | 32 | Sept. 26 | 22 | ........ | ........ | 22 |
| 7 | July 13 | 37 | 31 | ........ | 6 | 33 | Sept. 29 | 23 | ........ | ........ | 23 |
| 8 | July 16 | 46 | 34 | ........ | 12 | 34 | Oct. 2 | 13 | ........ | ........ | 13 |
| 9 | July 19 | 57 | 38 | ........ | 19 | 35 | Oct. 5 | 10 | ........ | ........ | 10 |
| 10 | July 22 | 73 | 67 | ........ | 6 | 36 | Oct. 8 | 5 | ........ | ........ | 5 |
| 11 | July 25 | 38 | 29 | ........ | 9 | 37 | Oct. 11 | 13 | ........ | ........ | 13 |
| 12 | July 28 | 39 | 31 | ........ | 8 | 38 | Oct. 14 | 11 | ........ | ........ | 11 |
| 13 | July 31 | 52 | 25 | ........ | 27 | 39 | Oct. 17 | 22 | ........ | ........ | 22 |
| 14 | Aug. 3 | 45 | 21 | ........ | 24 | 40 | Oct. 20 | 15 | ........ | ........ | 15 |
| 15 | Aug. 6 | 38 | 11 | ........ | 27 | 41 | Oct. 23 | 2 | ........ | ........ | 2 |
| 16 | Aug. 9 | 32 | 5 | ........ | 27 | 42 | Oct. 26 | 3 | ........ | ........ | 3 |
| 17 | Aug. 12 | 16 | 2 | ........ | 14 | 43 | Oct. 29 | 2 | ........ | ........ | 2 |
| 18 | Aug. 15 | 42 | 4 | ........ | 38 | 44 | Nov. 1 | 0 | ........ | ........ | 0 |
| 19 | Aug. 18 | 28 | ........ | ........ | 28 | 45 | Nov. 4 | 0 | ........ | ........ | 0 |
| 20 | Aug. 21 | 26 | ........ | ........ | 26 | 46 | Nov. 7 | 1 | ........ | ........ | 1 |
| 21 | Aug. 24 | 17 | ........ | ........ | 17 | 47 | Nov 10 | 0 | ........ | ........ | 0 |
| 22 | Aug. 27 | 25 | ........ | ........ | 25 | 48 | Nov. 13 | 0 | ........ | ........ | 0 |
| 23 | Aug. 30 | 26 | ........ | ........ | 26 | 49 | Nov. 16 | 0 | ........ | ........ | 0 |
| 24 | Sept. 2 | 25 | ........ | ........ | 25 | 50 | Nov. 19 | 1 | ........ | ........ | 1 |
| 25 | Sept. 5 | 15 | ........ | ........ | 15 | | | | | | |
| 26 | Sept. 8 | 16 | ........ | ........ | 16 | Total...... | | 1,044 | 372 | 2 | 670 |

TABLE LXVIII.—*Band records of 1911; summaries of Tables LXIII–LXVII.*

| Observations. | Douglas. | | Lake shore. | | New Richmond. | | Benton Harbor. | | Pentwater. | | Average per cent. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total number. | Per cent. | Total number. | Per cent. | Total number. | Per cent. | Total number. | Per cent. | Total number. | Per cent. | |
| Larvæ collected from the bands............ | 517 | 100.0 | 1,125 | 100.0 | 434 | 100.0 | 1,567 | 100.0 | 1,044 | 100.0 | 100.0 |
| Moths emerging, 1911.. | 91 | 17.6 | 287 | 25.5 | 90 | 20.7 | 441 | 28.1 | 372 | 35.6 | 25.5 |
| Parasites emerging, 1911 | 19 | 3.7 | 9 | .8 | 9 | 2.1 | 35 | 2.3 | 2 | .2 | 1.8 |
| Larvæ of the first brood................ | 261 | 50.5 | 775 | 68.9 | 268 | 61.7 | 1,008 | 64.3 | 717 | 68.7 | 62.8 |
| Transforming larvæ of first brood........... | 91 | 34.9 | 287 | 37.0 | 90 | 33.6 | 441 | 43.7 | 372 | 51.9 | 40.0 |
| Wintering larvæ of first brood........... | 170 | 65.1 | 488 | 63.0 | 178 | 66.4 | 567 | 56.3 | 345 | 48.1 | 60.0 |
| Larvæ of the second brood................ | 256 | 49.5 | 350 | 31.1 | 166 | 38.3 | 559 | 35.7 | 327 | 31.3 | 37.2 |
| Wintering larvæ of first and second broods............... | 407 | 78.7 | 829 | 73.7 | 335 | 77.2 | 1,091 | 69.6 | 670 | 64.2 | 72.7 |

The averages for the different observations show that from the total number of larvæ only 25.5 per cent transformed and issued as moths in 1911; adult parasites issued in 1911 from 1.8 per cent of the codling-moth larvæ; 62.8 per cent of the larvæ were of the first brood and 37.2 per cent of the second brood; of the first-brood larvæ 40 per cent transformed and 60 per cent wintered; of both the first and second broods 72.7 per cent of the larvæ wintered.

## SUMMARY OF SEASONAL-HISTORY STUDIES OF 1911.

The prevailing high temperature of the season produced a marked shortening in the time of development of the codling moth. The deviation from the average conditions is only slightly noticeable within the separate stages, but becomes strikingly marked for the whole life cycle. Thus the time of hatching of the earliest larvæ of the second brood came 21 days ahead of those for the previous year, and the time of hatching of the second-brood larvæ extended over an unusually long period of two and a half months. The second-brood larvæ were exceptionally abundant, being in some orchards equal in numbers with those of the first brood. In figure 20 a summary is given in a graphical form to illustrate the progress of the development of the codling moth in the course of the whole season of 1911.

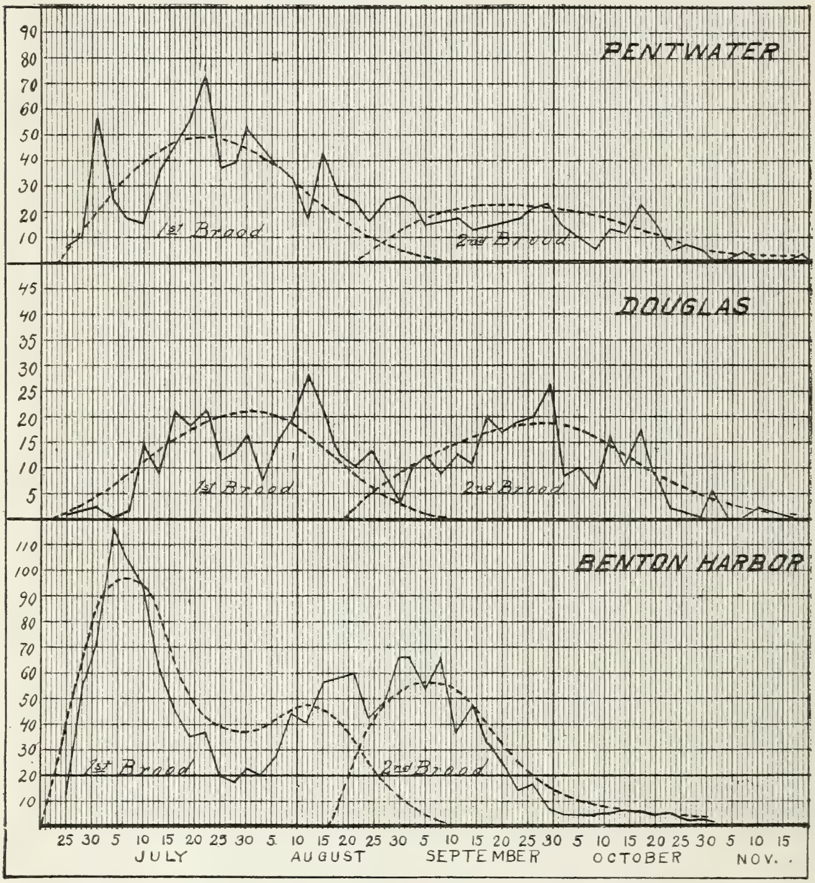

FIG. 19.—Curves made from band-record experiments in orchards at Pentwater, Douglas, and Benton Harbor, Mich., 1911. (Original.)

## WEATHER RECORDS FOR 1909, 1910, AND 1911.

Considering the variation in the time of transformation of the codling moth during the three years of observation, it becomes evident that the insect is largely governed by climatic conditions. This is only natural, since phytophagous insects, depending upon the development of their host plants, must to a certain degree be governed by the same phenological laws that govern these plants The earliest codling moths of the spring brood generally appear at a time shortly after the blooming period of apple, so that the early larvæ will hatch after the setting of the young fruit. A full consideration of climatic conditions during the years 1909, 1910, and 1911 is therefore given for a better interpretation of the life-history studies.

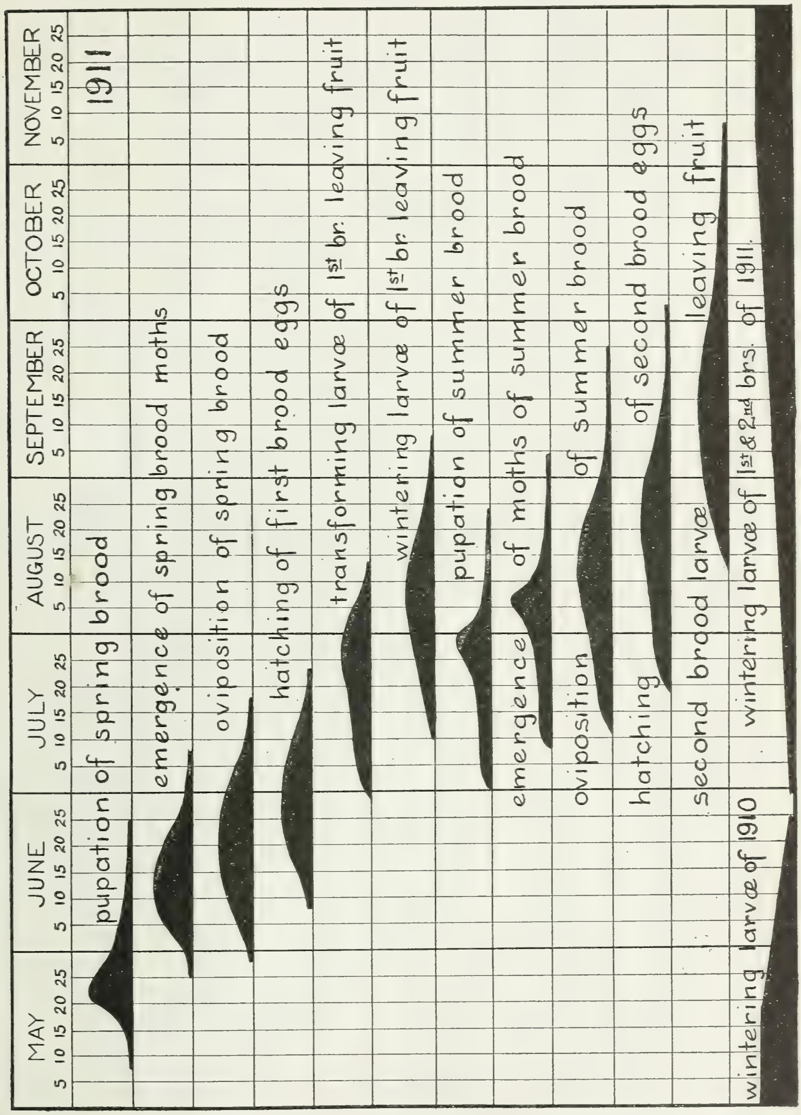

Fig. 20.—Diagram illustrating seasonal history of the codling moth as observed during 1911, at Douglas, Mich. (Original.)

A self-recording thermometer of the type generally used by the United States Weather Bureau was kept in the rearing shelter throughout the seasons of 1910 and 1911, and the records of the temperature conditions are given in Tables LXIX and LXX in degrees Fahrenheit. The average daily temperature in these tables represents the averages from hourly readings for each day. The readings of maximum and minimum degrees of temperature were taken from a special maximum and minimum instrument. Daily record was also kept on the general weather conditions. For the preparation of the following account of climatic conditions the writer has in addition made extensive use of the reports of the United States Weather Bureau.

The season of 1909 was characterized by a cool and wet April, by heavy rains during July, and by an exceptionally warm November. During the month of May rather cold and dry weather prevailed. During June the temperature as a whole was seasonable, although there were an unusually large number of rainy days. The temperature for July averaged slightly below normal, and the precipitation was far in excess of normal. During August the temperature averaged several degrees above the normal and the rainfall was slightly in excess in the southern parts of the peninsula. September, on the contrary, was marked by a somewhat low temperature and a deficiency of precipitation, October was unseasonably cool and rather dry, while November as a whole was unusually warm.

The spring of 1910 in many of its features was unprecedented, as is well stated by the United States Weather reports for March:

> The excessive warmth, the extreme dryness both as regards precipitation and relative humidity, the large number of clear days with bright sunshine, the early disappearance of snow and ice, the light wind movement, and the absence of serious storms makes a history for the month (March) without parallel since the beginning of the official records. Never since the Weather Bureau was established has there been such an early opening spring. As a whole, the conditions that prevailed at the close of the month were those usually experienced from three to five weeks later.

The warm weather of March continued through the first two weeks of April, when many deciduous fruit trees were out in full bloom. Following this warm weather, at a very critical period for the orchards, a drop of temperature occurred, which was accompanied by a storm with rain and snow and severe freezing. The cool weather which prevailed during the latter half of April continued with slight interruption throughout the month of May and the first half of June. Vegetation was not merely greatly retarded, but badly damaged, and the season was exceptionally backward. In striking contrast to this low-temperature condition came warm weather, which was rather above normal, extending over the latter half of June and all of July. August was fairly normal. During these last months precipitation was below the average, and clear bright weather prevailed mostly throughout. The weather conditions during September and October were fairly normal. A marked drop in temperature set in during late October, which brought most insect activity to a standstill for the rest of the season. The month of November, in striking contrast with 1909, was cloudy and cold.

The uniform spring of 1911 was very favorable for the development of fruit and leaf buds, which were not unduly forwarded. The weather during April was rather more severe than usual until the last week of the month, when a pronounced warm spell set in, which advanced rapidly the growth of vegetation. The mean temperature for May was decidedly above normal, and an abundance of sunshine prevailed. The United States Weather Bureau pronounced the heat for the month unprecedented. Thunderstorms were frequent, accompanied by high winds and excessive rainfall. This weather condition continued without interruption throughout the greater part of June, when severe storms occurred, which caused great damage to orchards and the fruit crop. During the period from the 11th to the 18th, at the height of the emergence period of the spring brood of moths, a markedly low temperature prevailed, accompanied by frequent rains, which caused a sudden and prolonged delay in the appearance of the moths. The weather conditions during July were also very exceptional. The first week of the month was marked by excessive heat and great dryness, while during the latter half of the month decidedly cold weather prevailed, with frequent local showers. August in most respects was normal, while September was marked by sharp alternation of warm and cold periods and a frequency of rainfalls. During October, and particularly during November, cool weather prevailed, which delayed considerably the time for the maturity of many second-brood codling-moth larvæ.

Table LXIX.—*Temperature records taken in the outdoor rearing shelter, showing maximum, minimum, and average daily temperatures, Douglas, Mich., 1910.*

| Date. | April. | | | May. | | | June. | | | July. | | | August. | | | September. | | | October. | | | November. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. |
| | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F | °F | °F. | °F | °F | °F. | °F | °F | °F. |
| 1.. | 61 | 39 | 49.9 | 64 | 48 | 54.5 | 51 | 41 | 45.2 | 87 | 59 | 72.5 | 74 | 56 | 68.2 | 70 | 50 | 59.5 | 65 | 44 | 58.0 | 50 | 38 | 46.9 |
| 2.. | 71 | 42 | 55.7 | 54 | 43 | 50.5 | 46 | 39 | 42.5 | 94 | 61 | 77.0 | 80 | 62 | 69.3 | 74 | 46 | 61.5 | 66 | 44 | 55.6 | 42 | 34 | 37.4 |
| 3.. | 68 | 48 | 59.0 | 54 | 40 | 45.3 | 54 | 42 | 46.7 | 81 | 62 | 71.1 | 78 | 66 | 72.5 | 72 | 62 | 66.4 | 83 | 58 | 68.2 | 44 | 28 | 35.5 |
| 4.. | 72 | 59 | 65.0 | 49 | 36 | 43.4 | 64 | 47 | 56.0 | 80 | 58 | 69.0 | 71 | 50 | 65.2 | 67 | 60 | 64.0 | 66 | 63 | 64.5 | 46 | 26 | 33.4 |
| 5.. | 74 | 50 | 64.6 | 53 | 33 | 43.8 | 58 | 44 | 51.8 | 86 | 54 | 70.4 | 72 | 50 | 63.3 | 72 | 64 | 70.4 | 72 | 57 | 65.0 | 40 | 32 | 36.0 |
| 6.. | 58 | 33 | 44.1 | 58 | 33 | 47.7 | 56 | 43 | 47.1 | 82 | 62 | 72.6 | 74 | 48 | 62.2 | 73 | 60 | 67.4 | 57 | 39 | 47.7 | 32 | 30 | 30.2 |
| 7.. | 41 | 30 | 36.0 | 60 | 38 | 53.0 | 57 | 44 | 49.9 | 77 | 60 | 69.6 | 75 | 56 | 64.6 | 81 | 54 | 69.0 | 62 | 34 | 47.8 | 46 | 31 | 37.0 |
| 8.. | 69 | 29 | 51.2 | 53 | 46 | 49.9 | 67 | 42 | 56.9 | 88 | 58 | 76.6 | 79 | 54 | 66.9 | 75 | 61 | 68.6 | 61 | 40 | 53.8 | 46 | 34 | 37.0 |
| 9.. | 59 | 43 | 49.7 | 60 | 41 | 49.5 | 74 | 53 | 63.7 | 89 | 65 | 74.2 | 74 | 64 | 69.6 | 60 | 42 | 54.6 | 58 | 44 | 51.7 | 56 | 40 | 48.5 |
| 10.. | 71 | 38 | 56.2 | 60 | 40 | 50.5 | 73 | 50 | 62.2 | 72 | 65 | 68.7 | 72 | 56 | 67.2 | 64 | 39 | 52.9 | 58 | 36 | 49.0 | 44 | 30 | 37.0 |
| 11.. | 58 | 35 | 50.0 | 54 | 36 | 44.8 | 66 | 50 | 56.4 | 81 | 67 | 73.4 | 77 | 50 | 64.2 | 77 | 43 | 62.5 | 66 | 54 | 61.2 | 36 | 30 | 32.7 |
| 12.. | 57 | 32 | 42.2 | 48 | 32 | 42.6 | 70 | 46 | 60.0 | 78 | 64 | 69.6 | 82 | 52 | 67.9 | 74 | 50 | 60.8 | 60 | 42 | 53.1 | 38 | 34 | 36.0 |
| 13.. | 59 | 29 | 45.0 | 47 | 34 | 40.9 | 78 | 53 | 64.0 | 76 | 56 | 67.0 | 81 | 59 | 70.1 | 64 | 46 | 53.6 | 69 | 40 | 53.9 | 39 | 33 | 35.2 |
| 14.. | 76 | 41 | 60.2 | 53 | 29 | 41.8 | 76 | 52 | 65.6 | 82 | 58 | 71.7 | 78 | 60 | 68.7 | 64 | 45 | 54.5 | 71 | 52 | 60.4 | 33 | 30 | 31.4 |
| 15.. | 73 | 61 | 67.2 | 65 | 37 | 51.5 | 73 | 54 | 64.7 | 82 | 68 | 75.0 | 84 | 63 | 73.4 | 70 | 43 | 56.7 | 61 | 50 | 55.2 | 34 | 31 | 32.9 |
| 16.. | 74 | 39 | 58.9 | 70 | 46 | 58.0 | 80 | 55 | 69.8 | 82 | 64 | 72.5 | 80 | 68 | 72.6 | 72 | 47 | 59.4 | 73 | 58 | 64.3 | 33 | 28 | 30.7 |
| 17.. | 52 | 37 | 43.1 | 58 | 47 | 53.6 | 80 | 67 | 73.1 | 77 | 58 | 67.7 | 80 | 64 | 72.3 | 66 | 52 | 60.3 | 78 | 52 | 62.0 | 30 | 28 | 28.2 |
| 18.. | 42 | 34 | 38.0 | 62 | 46 | 54.3 | 80 | 62 | 70.1 | 76 | 53 | 63.6 | 74 | 59 | 68.0 | 74 | 55 | 63.7 | 81 | 53 | 64.9 | 31 | 29 | 30.0 |
| 19.. | 45 | 39 | 40.9 | 71 | 52 | 61.3 | 74 | 60 | 68.3 | 76 | 51 | 64.0 | 76 | 53 | 63.9 | 68 | 53 | 57.7 | 78 | 58 | 66.9 | 38 | 24 | 29.4 |
| 20.. | 48 | 38 | 43.7 | 68 | 54 | 61.0 | 74 | 60 | 67.8 | 77 | 56 | 69.8 | 74 | 55 | 66.0 | 67 | 50 | 60.2 | 57 | 46 | 50.4 | 43 | 23 | 32.4 |
| 21.. | 62 | 34 | 46.9 | 77 | 54 | 62.3 | 87 | 65 | 76.6 | 79 | 65 | 72.3 | 83 | 60 | 73.4 | 74 | 49 | 59.5 | 53 | 46 | 49.4 | 36 | 30 | 33.0 |
| 22.. | 66 | 39 | 53.4 | 74 | 52 | 62.4 | 86 | 66 | 75.5 | 76 | 66 | 68.5 | 83 | 70 | 76.0 | 72 | 45 | 59.3 | 52 | 46 | 48.8 | 40 | 30 | 34.8 |
| 23.. | 37 | 31 | 32.8 | 62 | 45 | 52.8 | 86 | 72 | 75.7 | 84 | 66 | 74.2 | 78 | 63 | 70.7 | 66 | 57 | 60.0 | 61 | 39 | 48.4 | 47 | 32 | 38.5 |
| 24.. | 43 | 32 | 37.4 | 58 | 45 | 52.3 | 84 | 60 | 73.3 | 80 | 64 | 70.8 | 82 | 73 | 76.9 | 68 | 57 | 60.4 | 62 | 45 | 53.9 | 42 | 34 | 38.0 |
| 25.. | 42 | 36 | 38.9 | 56 | 43 | 48.5 | 84 | 55 | 69.5 | 79 | 62 | 71.1 | 78 | 58 | 68.4 | 57 | 48 | 54.7 | 58 | 40 | 50.1 | 40 | 30 | 36.1 |
| 26.. | 57 | 36 | 44.2 | 50 | 42 | 46.2 | 81 | 55 | 70.2 | 85 | 59 | 73.4 | 68 | 50 | 60.4 | 65 | 45 | 57.1 | 60 | 44 | 51.0 | 44 | 24 | 33.2 |
| 27.. | 54 | 40 | 45.6 | 60 | 39 | 50.4 | 74 | 61 | 67.8 | 77 | 64 | 70.2 | 71 | 48 | 60.8 | 58 | 53 | 55.1 | 50 | 34 | 42.6 | 38 | 32 | 34.1 |
| 28.. | 63 | 42 | 53.5 | 74 | 40 | 62.1 | 78 | 53 | 66.2 | 82 | 59 | 70.9 | 75 | 53 | 64.1 | 64 | 43 | 52.6 | 34 | 30 | 32.0 | 36 | 32 | 33.3 |
| 29.. | 74 | 56 | 65.2 | 62 | 46 | 54.5 | 80 | 56 | 69.9 | 80 | 61 | 72.8 | 76 | 58 | 67.0 | 66 | 42 | 55.0 | 35 | 30 | 31.8 | 31 | 28 | 29.8 |
| 30.. | 56 | 44 | 47.7 | 47 | 43 | 45.0 | 83 | 60 | 72.3 | 72 | 60 | 67.2 | 81 | 60 | 70.4 | 72 | 51 | 64.0 | 52 | 29 | 43.4 | 33 | 28 | 30.3 |
| 31.. | .... | .... | .... | 42 | 40 | 41.0 | .... | .... | .... | 72 | 48 | 62.3 | 76 | 59 | 66.3 | ... | ... | .... | 58 | 32 | 47.4 | ... | ... | .... |

Note.—The records from Apr. 1 to 20, inclusive, were taken from Mr. Tillinghast's records at Douglas, Mich.

Table LXX.—*Temperature records taken in the outdoor rearing shelter, showing maximum, minimum, and average daily temperatures, Douglas, Mich., 1911.*

| Date. | May. | | | June. | | | July. | | | August. | | | September. | | | October. | | | November. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. |
| | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. |
| 1 | 58 | 32 | 41.5 | 70 | 49 | 61.0 | 89 | 67 | 79.2 | 76 | 66 | 70.8 | 83 | 55 | 69.5 | 54 | 50 | 51.8 | 41 | 28 | 35.3 |
| 2 | 44 | 33 | 36.5 | 69 | 48 | 63.0 | 89 | 75 | 80.8 | 73 | 59 | 66.2 | 77 | 54 | 67.1 | 60 | 46 | 52.7 | 33 | 25 | 29.7 |
| 3 | 52 | 35 | 42.9 | 80 | 60 | 66.9 | 92 | 73 | 81.2 | 76 | 55 | 66.3 | 70 | 49 | 59.8 | 69 | 44 | 54.0 | 41 | 30 | 34.2 |
| 4 | 59 | 38 | 43.3 | 84 | 62 | 70.8 | 94 | 88 | 83.1 | 81 | 63 | 70.2 | 81 | 47 | 65.2 | 60 | 49 | 55.4 | 40 | 31 | 35.9 |
| 5 | 59 | 31 | 43.6 | 75 | 52 | 65.2 | 95 | 78 | 86.0 | 85 | 69 | 73.7 | 75 | 61 | 65.7 | 50 | 37 | 46.7 | 48 | 38 | 41.8 |
| 6 | 72 | 26 | 51.9 | 70 | 59 | 63.2 | 79 | 68 | 73.7 | 86 | 61 | 74.3 | 63 | 59 | 60.8 | 62 | 46 | 52.3 | 50 | 42 | 49.5 |
| 7 | 74 | 43 | 59.7 | 68 | 54 | 60.8 | 85 | 65 | 74.4 | 88 | 64 | 77.0 | 73 | 57 | 62.2 | 55 | 36 | 46.0 | 44 | 40 | 41.8 |
| 8 | 75 | 51 | 61.3 | 75 | 53 | 65.9 | 89 | 66 | 78.9 | 74 | 69 | 69.4 | 70 | 56 | 67.9 | 56 | 31 | 44.5 | 50 | 33 | 40.2 |
| 9 | 76 | 55 | 62.4 | 84 | 62 | 75.3 | 89 | 73 | 79.7 | 84 | 57 | 70.7 | 64 | 53 | 60.1 | 63 | 38 | 49.6 | 47 | 33 | 41.3 |
| 10 | 82 | 54 | 68.9 | 86 | 67 | 74.9 | 89 | 73 | 77.2 | 87 | 62 | 73.1 | 71 | 53 | 61.9 | 60 | 48 | 52.7 | 59 | 48 | 52.4 |
| 11 | 64 | 55 | 60.3 | 78 | 64 | 66.2 | 87 | 71 | 78.2 | 78 | 64 | 67.4 | 73 | 58 | 64.9 | 60 | 46 | 52.0 | 72 | 46 | 62.4 |
| 12 | 68 | 42 | 52.5 | 64 | 53 | 59.2 | 78 | 60 | 67.1 | 73 | 57 | 65.3 | 62 | 52 | 55.4 | 59 | 43 | 50.0 | 39 | [1] 20 | [1] 23.1 |
| 13 | 65 | 36 | 48.5 | 66 | 51 | 58.8 | 78 | 59 | 70.8 | 78 | 60 | 67.0 | 67 | 48 | 56.3 | 64 | 42 | 51.9 | 25 | [1] 20 | [1] 23.2 |
| 14 | 75 | 47 | 61.4 | 72 | 53 | 61.2 | 79 | 68 | 69.1 | 81 | 67 | 73.4 | 70 | 50 | 60.6 | 59 | 48 | 53.2 | 33 | 24 | 27.2 |
| 15 | 79 | 55 | 68.7 | 72 | 53 | 63.3 | 82 | 57 | 70.6 | 76 | 67 | 69.6 | 72 | 61 | 66.2 | 63 | 47 | 53.0 | 34 | 26 | 30.4 |
| 16 | 79 | 58 | 68.8 | 68 | 60 | 63.4 | 72 | 63 | 65.7 | 81 | 69 | 73.3 | 73 | 50 | 62.8 | 76 | 50 | 63.1 | 34 | 21 | 27.0 |
| 17 | 79 | 64 | 71.9 | 69 | 60 | 62.3 | 72 | 54 | 61.9 | 77 | 67 | 70.9 | 82 | 53 | 68.5 | 57 | 42 | 53.7 | 48 | 30 | 35.5 |
| 18 | 84 | 64 | 74.7 | 73 | 55 | 63.7 | 79 | 54 | 68.4 | 78 | 63 | 66.3 | 74 | 61 | 66.7 | 64 | 41 | 53.3 | 34 | 26 | 28.5 |
| 19 | 86 | 72 | 79.2 | 78 | 55 | 68.1 | 75 | 64 | 67.7 | 69 | 51 | 60.0 | 64 | 48 | 59.2 | 54 | 46 | 50.2 | 32 | 27 | 29.8 |
| 20 | 85 | 59 | 70.0 | 76 | 62 | 69.5 | 77 | 53 | 66.4 | 70 | 49 | 60.9 | 68 | 45 | 57.9 | 53 | 45 | 47.9 | 34 | 28 | 31.6 |
| 21 | 74 | 61 | 69.8 | 79 | 55 | 70.1 | 72 | 64 | 66.0 | 80 | 53 | 68.5 | 68 | 47 | 56.3 | 51 | 43 | 45.9 | 34 | 28 | 31.3 |
| 22 | 76 | 60 | 65.0 | 85 | 65 | 76.9 | 75 | 53 | 68.0 | 72 | 66 | 65.3 | 70 | 44 | 56.2 | 48 | 42 | 44.3 | 37 | 28 | 33.0 |
| 23 | 70 | 60 | 61.4 | 87 | 67 | 77.3 | 76 | 56 | 63.7 | 71 | 51 | 59.9 | 72 | 50 | 62.4 | 46 | 42 | 44.5 | 38 | 28 | 32.6 |
| 24 | 72 | 54 | 58.0 | 82 | 59 | 69.7 | 68 | 53 | 59.6 | 70 | 56 | 59.3 | 67 | 59 | 62.0 | 51 | 41 | 45.3 | 31 | 26 | 28.0 |
| 25 | 82 | 57 | 70.3 | 80 | 69 | 73.1 | 66 | 53 | 59.8 | 72 | 45 | 57.9 | 60 | 50 | 56.9 | 57 | 41 | 47.4 | 39 | 30 | 34.7 |
| 26 | 82 | 63 | 72.1 | 83 | 68 | 74.9 | 71 | 51 | 62.3 | 78 | 49 | 63.4 | 63 | 43 | 53.9 | 50 | 32 | 39.1 | 48 | 34 | 38.4 |
| 27 | 89 | 64 | 78.2 | 77 | 67 | 68.6 | 77 | 49 | 64.2 | 79 | 59 | 68.5 | 68 | 47 | 61.0 | 44 | 30 | 35.3 | 47 | 32 | 38.6 |
| 28 | 68 | 61 | 62.9 | 64 | 58 | 60.3 | 78 | 56 | 69.2 | 69 | 59 | 62.7 | 63 | 42 | 54.2 | 47 | 33 | 40.7 | 38 | 26 | 33.6 |
| 29 | 74 | 55 | 64.5 | 74 | 48 | 63.1 | 78 | 61 | 65.3 | 66 | 46 | 55.7 | 62 | 47 | 53.9 | 51 | 42 | 46.5 | 32 | 21 | 27.7 |
| 30 | 75 | 52 | 65.3 | 83 | 47 | 74.3 | 82 | 62 | 73.7 | 74 | 44 | 58.2 | 56 | 46 | 50.6 | 48 | 41 | 43.9 | 34 | 27 | 31.2 |
| 31 | 67 | 58 | 60.0 | .... | .... | ..... | 86 | 63 | 76.0 | 74 | 53 | 59.5 | .... | .... | ..... | 44 | 38 | 40.1 | .... | .... | ..... |

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[1] Temperatures below 20° F. not recorded.

## COMPARATIVE LIFE-HISTORY STUDIES FOR THE SEASONS OF 1909, 1910, AND 1911.

On considering the seasonal variations in the time of transformation and the relative abundance of the codling moth it is evident that the climatic conditions, and mainly the temperature, are the direct governing factors. Sometimes a scarcity of fruit may materially reduce the normal abundance of the codling moth. The effect of climatic variations upon the life of the insect is particularly noticeable in the spring, when the relative earliness of the season is followed by a corresponding change in the time of emergence of the moths. From the curves of figures 1, 6, and 14, which represent the time of emergence of the spring moths for the respective years of 1909, 1910, and 1911, with temperature records for the last two years, it will be noted that under prevailing uniform temperatures the emergence for the main portion of the moths becomes limited to a short period, as occurred in 1910, while on the other hand under fluctuating temperatures the emergence is very irregular and extends over a much longer period of time, as observed in 1911.

The time of the emergence of the earliest moths has closely followed the time of blossoming of apples and occurred from 5 to 10 days after the blossoms dropped (Baldwin apples). By adding to these figures the time of flight of the moths previous to oviposition and the time of incubation of the eggs it was found that fully three weeks elapsed before the hatching of the earliest larvæ of the first brood.

In 1909 the moths commenced to appear at a normal time, but were somewhat delayed in reaching a maximum of emergence. The season as a whole was fairly normal. The late fall, together with other favorable influences, produced a development of a very large second brood of larvæ. Of the total number of larvæ for the year, 43 per cent were of the first brood and 57 per cent of the second brood. This occurrence was perhaps directly due to the unusual rate of emergence of the moths of the summer brood. These commenced to appear at the normal time, but already reached a maximum during the early part of August (fig. 21) instead of the latter part of the month, which is the general tendency as shown for 1910. In the band-record curves of figure 22 is shown a corresponding rate in the time of maturity of larvæ of the second brood. The maximum in the first brood of larvæ occurred comparatively late,

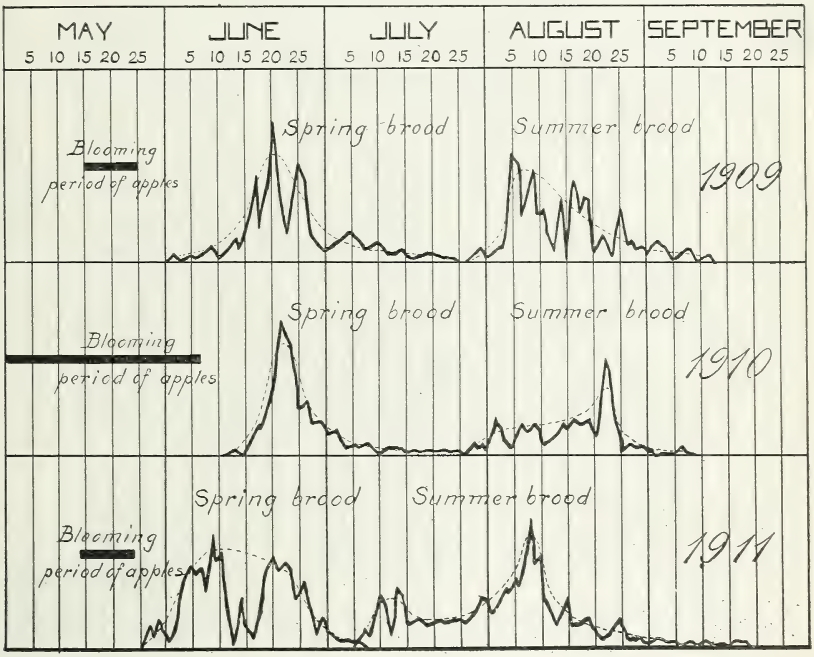

FIG. 21.—Diagram showing time of emergence and relative abundance of spring-brood and summer-brood codling moths, and blooming period of apple trees, during 1909, 1910, and 1911 at Douglas, Mich. (Original.)

which in turn reduced the percentages of transforming larvæ as against the percentage of wintering larvæ of the same brood (see Table LXXI). The occurrence of an early maximum of larvæ in the second-brood larvæ was due to the early rate of emergence of the moths of the summer brood, and to favorable climatic conditions.

During 1910 the codling moths of the spring brood were delayed in the time of emergence of the earliest individuals. The larger number of moths, however, emerged very soon after the first appearance of moths, so that for the rest of the season the dates for the occurrence of the separate stages were about normal. The summer moths commenced to appear July 26 and reached a maximum of abundance during late August, which has been observed to be the general rate of emergence for the brood. In 1910 the codling moth was naturally limited in numbers as a result of the small crop of apples, and to this must be ascribed the reduced size of the second brood. Of the total number of larvæ from the band records, 73.2 per cent were of the first brood and only 26.8 per cent of the second brood. In some sections of the Michigan fruit belt the apple crop was so limited that only one brood occurred, the fruit having dropped before the second brood developed.

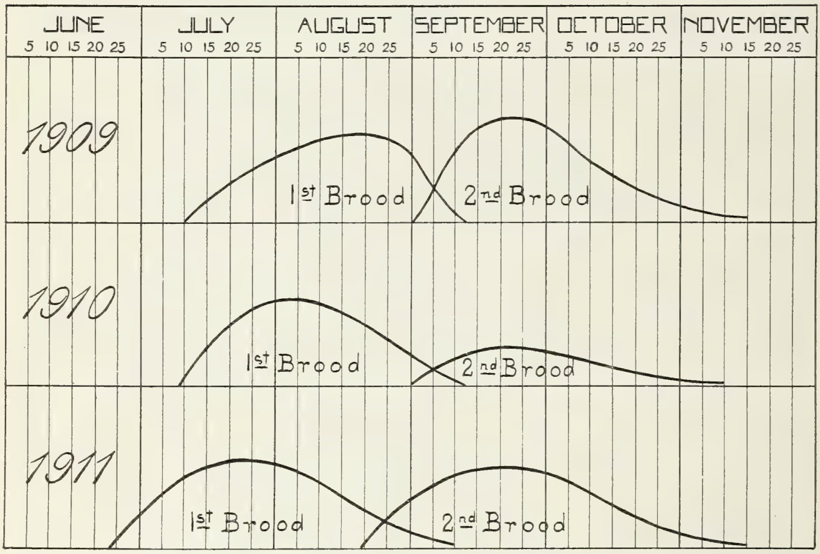

FIG. 22.—Diagram showing time of leaving the fruit by the first-brood and second-brood larvæ of the codling moth during 1909, 1910, and 1911, at Douglas, Mich. (Original.)

The spring of 1911 opened at a normal time. The temperature during the latter part of May and all of June was on an average exceptionally high, and this condition forwarded the development of both plants and insects in a very unusual manner. The moths commenced to emerge at a normal time, as compared with phenological developments. In the course of the emergence period part of the moths of the spring brood were hampered by cold rains, which set in during the middle of June and caused a somewhat prolonged delay for about one-half of the moths. This irregularity in the development of the insect produced an unusual effect upon the time and rate of occurrence of the separate stages for the rest of the season. This is noticeable from a study of the curves of figure 21 for 1911. In the summer brood there occurred an abundance of moths at the very start of the emergence, which was followed by a decrease in number as a result of the delay found in the spring brood; then again an abundance of moths appeared during the first half of August as a result of the emergence of the later half of the spring brood of moths. The prevailing high temperature advanced the earliest developing insects to the extent that the second-brood larvæ appeared three weeks ahead of those of 1910, and further prolonged to a very unusual extent the time of emergence of the summer moths, the period of egg deposition, and the period of hatching of the second brood of larvæ. The large fruit crop, together with the high temperature, favored the development of a large second brood of larvæ. For the total number of larvæ collected at the Douglas band records 50.5 per cent were of the first brood and 49.5 per cent of the second brood.

TABLE LXXI.—*Summary of results of band records for 1909, 1910, and 1911, at Douglas, Mich.*

| Observations. | Percentages for— | | |
|---|---|---|---|
| | 1909 | 1910 | 1911 |
| Moths emerging the same season | 13.2 | 25.5 | 17.6 |
| Moths emerging the following season | 55.7 | 39.7 | ........ |
| Total emergence of moths | 68.8 | 65.2 | ........ |
| Wintering larvæ of total band collection | 85.7 | 73.5 | 78.7 |
| Wintering larvæ killed by frost | 24.6 | 30.1 | ........ |
| Parasitized larvæ | 6.6 | 4.7 | ........ |
| Relative proportion of first-brood larvæ | 43.1 | 73.2 | 50.5 |
| Relative proportion of second-brood larvæ | 56.9 | 26.8 | 49.5 |
| Transforming larvæ of first brood | 33.2 | 34.8 | 34.9 |
| Wintering larvæ of first brood | 66.8 | 65.2 | 65.1 |

The results from the band records for the three years at Douglas show that of the first-brood larvæ about one-third transformed the same season and two-thirds passed the winter in the larval stage, as do all second-brood larvæ. (See Table LXXI.)

## INSECT ENEMIES.[1]

### PREDACEOUS INSECTS.

Several predaceous insects have been found to attack the larvæ and pupæ of the codling moth. Of these a small black beetle and its larva, *Tenebroides corticalis* Melsh. (Pl. III, figs. 4, 5), belonging to the family Trogositidæ, has been found to constitute one of the most important predatory insect enemies of the codling moth. The slender and flat form of the larva and also the depressed shape of the beetle enable the insect to penetrate into narrow cracks and crevices in search of prey. Both the larvæ and beetles have been found in the cocoons of the codling moth, having penetrated the walls of the same and destroyed the host. Full-grown larvæ and beetles have been collected in the late fall and in the spring, which would indicate that the insect passes the winter in both stages. The white and delicate pupa was once observed under the bark in a small cavity, which must have been made by the larvæ previous to pupation.

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[1] For information relative to the bird enemies of the codling moth, see Yearbook of the Department of Agriculture for 1911, pp. 199–208, "Bird Enemies of the Codling Moth," by W. L. McAtee.

There are several species of carabid beetles that have been found under the bands on apple trees. Of these *Pinacodera limbata* Dej. (Pl. III, fig. 3) and *Platynus placidus* Say were seen to destroy the larvæ of the codling moth. Mr. W. Postiff collected in 1910 one specimen of *Tenebroides castanea* Melsh., which also was destructive to codling moth larvæ. These specimens were kindly determined by Mr. E. A. Schwarz, of the Bureau of Entomology.

In wind fallen apples the codling moth larvæ are sometimes attacked by wireworms (species not determined), which have been found in wormy fruit. In confinement the wireworm larvæ fed freely upon codling moth larvæ, even after the latter were removed from the fruit.

The larvæ of a lacewing fly (*Chrysopa* sp.) were often observed in the act of absorbing the contents of the eggs of the codling moth. In the rearing shelter these insects were regular pests, in that they would destroy the eggs in the cages under observation whenever the eggs were left exposed. In the orchards the larvæ of the lacewing flies are very common and no doubt they play there an important rôle in checking the codling moth.

### PARASITIC INSECTS.

Among the native hymenopterous parasites of the codling moth *Ascogaster* (*Chelonus*) *carpocapsæ* Vier. (Pl. III, figs. 1, 2) is the most commonly observed. It has been collected in the States of Michigan, Pennsylvania, Maryland, Virginia, and Nebraska, and will probably be found in most localities where the codling moth occurs. The species was originally described by Mr. H. L. Viereck[1] from specimens collected at Douglas, Mich., in 1908 by Mr. R. W. Braucher. The writer also reared the insect in abundance at North East, Pa., in 1908 and 1909. The band records in 1909 at Douglas, Mich., showed that 6.6 per cent of the codling moth larvæ were parasitized, and in 1910 the separate band records showed the following extent of parasitism: New Richmond, 7.7 per cent, Saugatuck 4.7 per cent, and Lake Shore 7.25 per cent.

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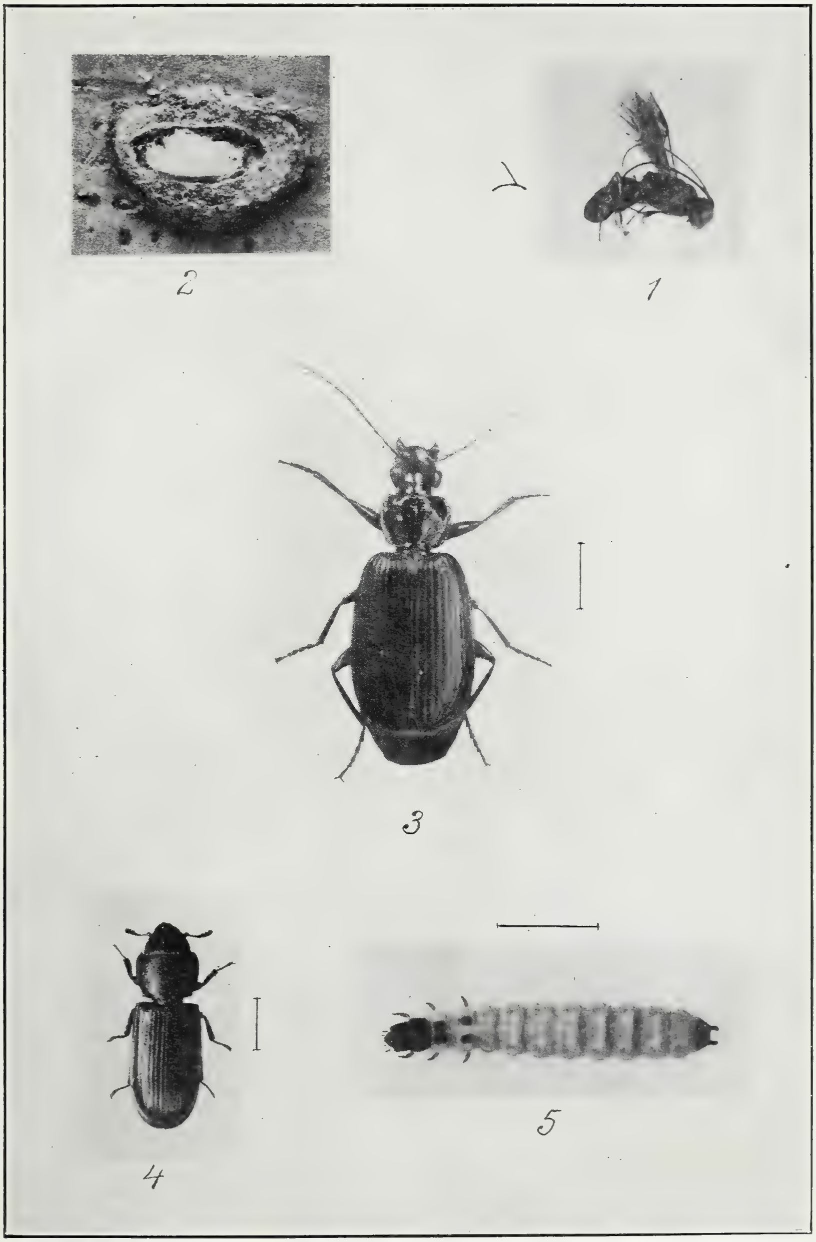
[1] Proc. Ent. Soc. Wash., vol. 11, p. 43, 1909.



INSECT ENEMIES OF THE CODLING MOTH.

FIG. 1.—*Ascogaster carpocapsæ*, a hymenopterous parasite of codling-moth larvæ. Fig. 2.—Cocoon of *Ascogaster carpocapsæ* within a cocoon of the codling moth, enlarged twice. Fig. 3.—*Pinacodera limbata*, a predaceous beetle destructive to codling-moth larvæ. Figs. 4, 5.—*Tenebroides corticalis*, beetle and larva, which feed upon the larva and pupa of the codling moth. (Original.)

The time of emergence of the adult parasites coincides with the time of emergence of the two broods of the codling moth. (Tables LXXII and LXXIII.) Like the host, the parasite is evidently two-brooded or possibly has a partial second brood.

Table LXXII.—*Time of emergence of the spring brood and the summer brood of Ascogaster carpocapsæ at Douglas, Mich., 1910.*

SPRING BROOD.

| Number of parasites. | Date of emergence. | Number of parasites. | Date of emergence. | Number of parasites. | Date of emergence. | Number of parasites. | Date of emergence. |
|---|---|---|---|---|---|---|---|
| 2 | June 22 | 9 | June 27 | 4 | July 2 | 1 | July 9 |
| 9 | June 23 | 2 | June 28 | 1 | July 3 | 1 | July 15 |
| 5 | June 24 | 14 | June 29 | 5 | July 5 | | |
| 11 | June 25 | 5 | June 30 | 3 | July 6 | 86 | |
| 10 | June 26 | 3 | July 1 | 1 | July 8 | | |

SUMMER BROOD.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | July 26 | 2 | Aug. 11 | 1 | Aug. 19 | 3 | Aug. 29 |
| 1 | July 30 | 3 | Aug. 12 | 5 | Aug. 20 | 1 | Aug. 30 |
| 2 | Aug. 2 | 3 | Aug. 13 | 6 | Aug. 22 | 2 | Sept. 5 |
| 5 | Aug. 4 | 3 | Aug. 14 | 2 | Aug. 23 | | |
| 1 | Aug. 5 | 6 | Aug. 15 | 2 | Aug. 24 | 72 | |
| 3 | Aug. 7 | 4 | Aug. 16 | 3 | Aug. 25 | | |
| 2 | Aug. 8 | 3 | Aug. 17 | 1 | Aug. 26 | | |
| 4 | Aug. 10 | 2 | Aug. 18 | 1 | Aug. 27 | | |

Table LXXIII.—*Time of emergence of spring and summer broods of Ascogaster carpocapsæ at Douglas, Mich., 1911.*

SPRING BROOD.

| Number of parasites. | Date of emergence. | Number of parasites. | Date of emergence. | Number of parasites. | Date of emergence. | Number of parasites. | Date of emergence. |
|---|---|---|---|---|---|---|---|
| 1 | June 2 | 3 | June 12 | 3 | June 19 | 2 | June 28 |
| 4 | June 5 | 2 | June 13 | 7 | June 20 | 1 | June 29 |
| 7 | June 6 | 4 | June 14 | 4 | June 21 | 1 | June 30 |
| 1 | June 8 | 5 | June 15 | 2 | June 22 | | |
| 4 | June 9 | 2 | June 16 | 6 | June 23 | 83 | |
| 7 | June 10 | 4 | June 17 | 4 | June 24 | | |
| 1 | June 11 | 7 | June 18 | 1 | June 26 | | |

SUMMER BROOD.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | July 9 | 6 | July 21 | 5 | Aug. 4 | 1 | Aug. 15 |
| 3 | July 11 | 1 | July 23 | 1 | Aug. 6 | 2 | Aug. 16 |
| 1 | July 12 | 2 | July 26 | 1 | Aug. 7 | 1 | Aug. 17 |
| 3 | July 13 | 2 | July 28 | 4 | Aug. 8 | 1 | Aug. 18 |
| 2 | July 14 | 2 | July 30 | 2 | Aug. 9 | 1 | Aug. 20 |
| 2 | July 15 | 5 | July 31 | 1 | Aug. 10 | 2 | Aug. 22 |
| 4 | July 16 | 1 | Aug. 1 | 2 | Aug. 11 | 2 | Aug. 27 |
| 1 | July 17 | 2 | Aug. 2 | 1 | Aug. 13 | 1 | Sept. 3 |
| 2 | July 19 | 1 | Aug. 3 | 5 | Aug. 14 | | |
| | | | | | | 74 | |

The time and stage of the development when the codling moth larvæ become parasitized are not definitely known. Probably many larvæ are parasitized after they leave the fruit and while in search of suitable places for the spinning of their cocoons. It is very evident that many larvæ are parasitized while still in the fruit, since adult parasites have been obtained from codling moth larvæ which were collected in windfallen fruit and confined in cages. At the time the parasitized codling moth larvæ leave the fruit they may readily be recognized by their inferior size and the absence of the pink color, which is characteristic of the full-grown codling moth larvæ. In the orchard on the grounds of the station, where numerous adult parasites had been liberated in the course of the season of 1911, fully 40 per cent of the band-record larvæ were parasitized in the late fall. The average measurement of the head of full-grown codling moth larvæ is 1.5 mm.; the parasitized larva at the time of leaving the fruit has an average head measurement of only 1.3 mm. In the spring of 1911, 15 undersized larvæ, lacking the pink color, were confined in a separate cage; of these, 10 proved later to be parasitized, while the rest died from other causes.

The parasite passes the winter in the larval stage within the host. The following spring feeding is terminated, and the host larva is completely devoured, except for the skin and the chitinous parts of the head. Within the cocoon of the host the parasite larva makes a small oval cocoon, white in color, within which it pupates shortly after. In 1911 one parasite pupated May 21 and issued as adult May 28, having remained 7 days in the pupal stage. So far as has been observed, only a single parasite develops in each host larva.

The parasitized codling moth larvæ that winter do not modify the cocoon in the spring as does the normal larva, which provides an exit for the issuing moth. The parasite fly is therefore forced to gnaw its way out through the walls of the cocoon.

### NEMATODE WORMS.

On September 1, 1910, the writer collected a windfallen apple with a full-grown codling moth larva which was found to be infested with minute, white-colored nematode worms (species not determined). The entire body cavity of the larva was filled with the worms and quite a number of worms were also found in the burrows in the apple, where the mass of worms had the general appearance of mildew growth.

## MISCELLANEOUS OBSERVATIONS.

### NUMBER OF LARVAL INSTARS AND MOLTS OF THE CODLING MOTH.

The codling moth, like all arthropods possessing an exoskeleton, must shed the skin from time to time in the course of its growth. The process of casting the skin is called "molting" (ecdysis) and the stages between the molts are termed "instars."

The determination of the number of instars of the codling moth becomes difficult because of the small size of the larva in the early stages and its habit of feeding within the fruit, where it can not readily be located for observation without great care and labor. Mr. E. L. Jenne,[1] in his studies of the codling moth in the Ozarks, determined the number of molts of the larvæ by rearing them on small pieces of fruit in glass vials. The vials were frequently examined for the cast skin of the head, and on this basis the number of molts was established. Jenne encountered great difficulty in preventing the fruit from rotting and in maintaining the larvæ in a healthy condition. His records from 12 larvæ showed that 9 larvæ passed through 7 instars and 3 larvæ passed through 8 instars.

At Douglas, Mich., the writer, in determining the larval molts, made use of Dyar's [2] method of head measurements, on the basis that "the widths of the head of the larva in its successive stages follow a regular geometrical progression." By this method the necessity of finding the cast skin was eliminated and the larvæ could be reared in entire fruit or in large pieces of fruit. On the other hand, this practice involved a considerable amount of labor and additional difficulties both in the finding of the larvæ and the taking of the measurements.

TABLE LXXIV.—*Instars of the codling moth larvæ of the second brood, and head measurements in millimeters for each instar, Douglas, Mich., 1910.*

| No. of observation. | First instar. | | Second instar. | | Third instar. | | Fourth instar. | | Fifth instar. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Hatching. | Mm. | First molt. | Mm. | Second molt. | Mm. | Third molt. | Mm. | Fourth molt. | Mm. |
| 1 | Aug. 11 | 0.33 | Aug. 15 | 0.50 | Aug. 22 | 0.66 | Aug. 27 | 1.00 | Sept. 8 | 1.40 |
| 2 | Aug. 12 | .33 | Aug. 16 | .45 | Aug. 20 | .66 | do | 1.03 | (3) | |
| 3 | do | .33 | do | .50 | Aug. 23 | .63 | Sept. 5 | 1.00 | Sept. 1 | 1.30 |
| 4 | Aug. 16 | .33 | Aug. 21 | .48 | Aug. 27 | .66 | (3) | .91 | Sept. 12 | 1.20 |
| 5 | do | .33 | do | .55 | Aug. 25 | .73 | (3) | | | |
| 6 | do | .33 | do | .55 | do | .70 | (3) | | | |
| 7 | do | .33 | do | .46 | (3) | | | | | |
| 8 | do | .33 | do | .50 | Sept. 1 | .70 | (3) | | | |
| 9 | Aug. 20 | .33 | Sept. 3 | .40 | Sept. 7 | .65 | Sept. 22 | .87 | (3) | |
| 10 | do | .32 | Sept. 1 | .48 | Sept. 5 | .65 | Sept. 12 | .83 | Sept. 21 | 1.06 |

| No. of observation. | Sixth instar. | | Pupation. | Days duration of instars. | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fifth molt. | Mm. | Sixth molt. | First instar. | Second instar. | Third instar. | Fourth instar. | Fifth instar. | Sixth instar. |
| 1 | Sept. 20 | 1.60 | Pupation following spring. | 4 | 7 | 5 | 12 | 12 | Wintering. |
| 2 | | | | 4 | 4 | 7 | | | |
| 3 | Sept. 18 | 1.53 | | 4 | 7 | 4 | 5 | 17 | |
| 4 | Sept. 22 | 1.50 | | 5 | 6 | 9 | 7 | 10 | |
| 5 | | | | 5 | 4 | | | | |
| 6 | | | | 5 | 4 | | | | |
| 7 | | | | 5 | | | | | |
| 8 | | | | 5 | 11 | | | | |
| 9 | | | | 14 | 4 | 15 | | | |
| 10 | (4) | | | 12 | 4 | 7 | 9 | (4) | |

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[1] Bul. 80, Part I, Bur. Ent., U. S. Dept. Agr., 1909.
[2] Psyche, vol. 5, p. 420.
[3] Died.
[4] Wintered.

TABLE LXXV.—*Larval instars of the codling moth; head measurements in millimeters for each instar; duration of instars. Summary of Table LXXIV.*

| Observations. | Head measurements in mm. per instar. | | | | | | Days duration of instars. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First instar. | Second instar. | Third instar. | Fourth instar. | Fifth instar. | Sixth instar. | First instar. | Second instar. | Third instar. | Fourth instar. | Fifth instar. | Sixth instar. |
| Average | 0.33 | 0.48 | 0.67 | 0.94 | 1.24 | 1.54 | 6.3 | 5.7 | 7.9 | 8.2 | 13.0 | (1) |
| Maximum | .33 | .55 | .73 | 1.03 | 1.40 | 1.60 | 14 | 11 | 15 | 12 | 17 | (1) |
| Minimum | .32 | .40 | .63 | .83 | 1.06 | 1.50 | 4 | 4 | 4 | 5 | 10 | (1) |

(1) Winter.

The head measurements were all made by an ocular micrometer of a compound microscope. It was necessary to bring the larvæ to a perfectly quiet position before the readings could be made. In 1910 this was accomplished by placing a cover glass over the larvæ during the early stages. The larger larvæ were held in place between two broken pieces of glass and by a small glass cover placed above. The results of these readings are given in Table LXXIV. Four larvæ out of 10 reached maturity and entered their winter cocoons. Three of these passed through six instars and one larva passed through five instars. A summary of these readings has been brought together in Table LXXV. The average length of the entire feeding period was evidently prolonged beyond that of the normal. The records for the minimum length of time of each instar represent more nearly the normal.

In 1911 similar observations were again made for both first-brood and second-brood larvæ. To quiet the larvæ for the necessary readings they were held over a piece of ice under the microscope. The exposure of the larvæ to the ice was made as brief as possible and in most instances extended to a few seconds. It was found that the larvæ would resume their normal activities within a minute after the exposure, and this treatment seemed to have no material effect upon the larvæ so far as altering the normal numbers of molts, since the results of these tests are identical with those of 1910.

TABLE LXXVI.—*Observations on the instars of the first-brood codling-moth larvæ at Douglas, Mich., 1911.*

| Number of observation. | Date of hatching and molting, and larval head measurements in millimeters. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | First instar. | | Second instar. | | Third instar. | | Fourth instar. | | Fifth instar. | |
| | Hatched. | mm. | First molt. | mm. | Second molt. | mm. | Third molt. | mm. | Fourth molt. | mm. |
| 1 | June 19 | 0.35 | June 26 | 0.46 | July 1 | 0.66 | July 5 | 0.83 | July 9 | 1.10 |
| 2 | do | .35 | June 27 | .45 | | .65 | July 6 | .88 | do | 1.30 |
| 3 | June 27 | .35 | July 3 | .50 | July 6 | .68 | July 11 | .90 | July 16 | 1.18 |
| 4 | June 28 | .35 | do | .49 | do | .70 | July 9 | [1] 1.10 | July 13 | [1] 1.50 |
| 5 | do | .35 | | | July 9 | .60 | July 11 | .85 | July 17 | 1.15 |
| 6 | do | .35 | July 4 | .46 | July 8 | .65 | do | .85 | do | 1.15 |
| 7 | July 2 | .35 | July 6 | .46 | July 9 | .70 | | | July 12 | 1.30 |
| 8 | do | .35 | do | .49 | do | .65 | July 24 | .80 | Aug. 1 | 1.08 |
| 9 | do | .35 | | | July 11 | .62 | July 17 | .81 | | |
| 10 | June 7 | .35 | July 10 | .46 | July 14 | .60 | | | | |
| 11 | | | | | July 15 | .70 | July 19 | 1.00 | | |
| 12 | | | | | July 14 | .65 | July 20 | .89 | July 28 | 1.19 |
| 13 | | | | | do | .70 | July 18 | 1.08 | | |
| 14 | | | | | | | | | July 14 | 1.00 |

| No. of observation. | Date of hatching and molting, and larval head measurements in millimeters—Continued. | | | | Days duration of instars. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sixth instar. | | | Pupation, sixth molt. | First instar. | Second instar. | Third instar. | Fourth instar. | Fifth instar. |
| | Fifth molt. | mm. | Loft fruit. | | | | | | |
| 1 | July 13 | 1.40 | | | 7 | 5 | 4 | 4 | 4 |
| 2 | | | Aug. 2 | Aug. 8 | 8 | | | 3 | [1] 30 |
| 3 | July 20 | 1.50 | July 27 | Aug. 4 | 6 | 3 | 5 | 5 | 4 |
| 4 | | | July 23 | July 31 | 5 | 3 | 3 | 4 | [1] 18 |
| 5 | July 29 | 1.46 | Aug. 5 | Aug. 12 | | | 2 | 6 | 12 |
| 6 | July 20 | 1.46 | July 27 | Aug. 4 | 6 | 4 | 3 | 6 | 3 |
| 7 | July 29 | 1.57 | Aug. 10 | | 4 | 3 | | | [1] 17 |
| 8 | Aug. 22 | [1] 1.19 | [1] Aug. 30 | [1] 1.29 | 4 | 3 | [1] 15 | 8 | [1] 21 |
| 9 | | | | | | | 6 | | |
| 10 | | | | | 3 | 4 | | | |
| 11 | July 28 | 1.51 | July 31 | | | | 4 | | |
| 12 | Aug. 6 | 1.46 | | | | | 6 | 8 | 9 |
| 13 | July 25 | 1.50 | Aug. 4 | Aug. 8 | | | 4 | | |
| 14 | July 19 | 1.50 | July 27 | Aug. 1 | | | | | 5 |

| No. of observation. | Days duration of instars—Continued. | | | | Remarks. |
|---|---|---|---|---|---|
| | Sixth instar. | | | Total larval life. | |
| | Feeding. | In cocoon. | Total. | | |
| 1 | | | | | Died in sixth instar. |
| 2 | | | | | Moth emerged Aug. 21; below average size. |
| 3 | 7 | 8 | 15 | 50 | Moth emerged Aug. 19; below average size. |
| 4 | | | | 33 | Moth emerged Aug. 13; below average size. |
| 5 | 7 | 7 | 14 | 45 | Moth emerged Aug. 25; average size. |
| 6 | 7 | 8 | 15 | 37 | Moth emerged Aug. 16; below average size. |
| 7 | 12 | | | | Normal size; larvæ wintered. |
| 8 | | | | 59 | Deformed; died Sept. 9. |
| 9 | | | | | Deformed; died July 24. |
| 10 | | | | | Died July 18. |
| 11 | [1] 3 | | | | Died before pupation. |
| 12 | | | | | Moth emerged Aug. 21; normal size. |
| 13 | 10 | 4 | 14 | | Died Aug. 20. |
| 14 | 8 | 5 | 13 | | Moth emerged Aug. 12; normal size. |

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[1] Abnormal and not included in the summary.

TABLE LXXVII.—*Larval instars of the codling moth; head measurements in millimeters for each instar; days duration of instars. Summary of Table LXXVI.*

| Observations. | Head measurements in mm. per instar. | | | | | | Days duration of instars. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First instar. | Second instar. | Third instar. | Fourth instar. | Fifth instar. | Sixth instar. | First instar. | Second instar. | Third instar. | Fourth instar. | Fifth instar. | Sixth instar. Feeding. | Sixth instar. In cocoon. | Total larval life. |
| Average | 0.35 | 0.47 | 0.66 | 0.89 | 1.16 | 1.47 | 5.6 | 3.6 | 4.1 | 5.5 | 6.1 | 8.3 | 6.4 | 44.8 |
| Maximum | .35 | .50 | .70 | 1.08 | 1.30 | 1.57 | 8 | 5 | 6 | 8 | 12 | 12 | 8 | 59 |
| Minimum | .35 | .45 | .60 | .80 | 1.00 | 1.40 | 3 | 3 | 2 | 3 | 3 | 7 | 4 | 33 |

In the course of these studies there was a rather high percentage of mortality, but this was mainly due to the difficulty in properly removing the larvæ from the fruit.

TABLE LXXVIII.—*Instars of the codling moth larvæ of the second brood; head measurements in millimeters; days duration of the instars; Douglas, Mich., 1911.*

| No. of observations. | Date of hatching and molting, and larval head measurements in millimeters. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | First instar. | | Second instar. | | Third instar. | | Fourth instar. | | Fifth instar. | |
| | Hatched. | mm. | First molt. | mm. | Second molt. | mm. | Third molt. | mm. | Fourth. molt. | mm. |
| 1 | July 29 | Average 0.35 mm. | Aug. 2 | 0.45 | Aug. 6 | 0.75 | Aug. 11 | 0.81 | | |
| 2 | do | | Aug. 3 | .45 | Aug. 7 | [1] 1.00 | Aug. 12 | [1] 1.22 | | |
| 3 | do | | do | .49 | Aug. 8 | .78 | | | | |
| 4 | do | | do | .54 | Aug. 6 | .76 | | | | |
| 5 | Aug. 2 | | Aug. 7 | .46 | Aug. 13 | .75 | | | | |
| 6 | do | | Aug. 8 | .46 | Aug. 15 | .70 | | | | |
| 7 | Aug. 6 | | Aug. 10 | .43 | | | | | | |
| 8 | do | | do | .49 | | | | | | |
| 9 | do | | | | | | | | Aug. 18 | 1.22 |
| 10 | Aug. 7 | | | | Aug. 20 | .66 | Aug. 27 | [1] 1.08 | Sept. 2 | [1] 1.51 |
| 11 | Aug. 11 | | | | | .76 | do | [1] 1.19 | Aug. 31 | [1] 1.51 |
| 12 | Aug. 12 | | Aug. 20 | .50 | | | | | | |
| 13 | do | | Aug. 17 | .46 | Aug. 25 | .68 | | | | |
| 14 | do | | do | .46 | Aug. 24 | .67 | Sept. 1 | .81 | | |
| 15 | do | | Aug. 28 | .50 | | | | | | |
| 16 | do | | Aug. 26 | .49 | Aug. 28 | .71 | | | | |
| 17 | Aug. 14 | | Aug. 23 | .49 | do | .66 | Sept. 7 | | | |
| 18 | do | | Aug. 19 | .51 | do | .67 | | | | |
| 19 | Aug. 15 | | do | | | | | | Sept. 1 | 1.19 |
| 20 | Aug. 16 | | Aug. 25 | .50 | Sept. 2 | .67 | | | | |
| 21 | Aug. 18 | | Aug. 28 | .42 | | | | | | |
| 22 | do | | Aug. 25 | .46 | Sept. 2 | .60 | | | | |
| 23 | Aug. 24 | | | | | | Sept. 8 | .80 | Sept. 15 | 1.08 |
| 24 | do | | | | | | do | .81 | Sept. 18 | 1.08 |

[1] Abnormal and not included in the summary.

TABLE LXXVIII.—*Instars of the codling moth larvæ of the second brood; head measurements in millimeters; days duration of the instars; Douglas, Mich., 1911*—Contd.

| No. of observations. | Date of hatching and molting, and larval head measurements in millimeters—Continued. | | | | Days duration of instars. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sixth instar. | | | Pupation, sixth molt. | First instar. | Second instar. | Third instar. | Fourth instar. | Fifth instar. | Sixth instar. | |
| | Fifth molt. | mm. | Left fruit. | | | | | | | Feeding. | Wintering. |
| 1 | | | | Pupation the following spring. | 4 | 4 | 5 | | | | |
| 2 | | | | | 5 | 4 | 5 | | | | |
| 3 | | | | | 5 | 5 | | | | | |
| 4 | | | | | 5 | 3 | | | | | |
| 5 | | | | | 5 | 6 | | | | | |
| 6 | | | | | 6 | 7 | | | | | |
| 7 | | | | | 4 | | | | | | |
| 8 | | | | | 4 | | | | | | |
| 9 | Aug. 26 | 1.81 | Aug. 31 | | | | | | 8 | 5 | (2) |
| 10 | | | Sept. 18 | | | | 7 | 6 | (2) | | |
| 11 | | | Sept. 10 | | | | | 4 | (2) | | |
| 12 | | | | | 8 | | | | | | |
| 13 | | | | | 5 | 8 | | | | | |
| 14 | | | | | 5 | 7 | 8 | | | | |
| 15 | | | | | 16 | | | | | | |
| 16 | | | | | 14 | 2 | | | | | |
| 17 | | | | | 9 | 5 | 10 | | | | |
| 18 | | | | | 5 | 9 | | | | | |
| 19 | Sept. 6 | 1.57 | Sept. 18 | | | | | | 5 | 12 | (2) |
| 20 | | | | | 9 | 8 | | | | | |
| 21 | | | | | 10 | | | | | | |
| 22 | | | | | 7 | 8 | | | | | |
| 23 | Sept. 27 | 1.62 | Oct. 20 | | | | | 7 | 12 | 23 | (2) |
| 24 | Oct. 1 | 1.52 | Oct. 18 | | | | | 10 | 13 | 17 | (2) |

[1] Abnormal and not included in the summary.

[2] Wintered.

TABLE LXXIX.—*Larval instars of the codling moth; head measurements in millimeters for each instar; duration of instars; summary of Table LXXVIII.*

| Observations. | Head measurements in mm. per instar. | | | | | | Days duration of instars. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First instar. | Second instar. | Third instar. | Fourth instar. | Fifth instar. | Sixth instar. | First instar. | Second instar. | Third instar. | Fourth instar. | Fifth instar. | Sixth (feeding). |
| Average | 0.35 | 0.47 | 0.70 | 0.81 | 1.14 | 1.63 | 7 | 5.8 | 7 | 7 | 9.5 | 14.2 |
| Maximum | | .54 | .78 | .81 | 1.08 | 1.81 | 16 | 9 | 10 | 10 | 13 | 23 |
| Minimum | | .42 | .60 | .80 | 1.22 | 1.52 | 4 | 2 | 5 | 4 | 5 | 5 |

The records for the time of molting and the head measurements for the separate instars for the first brood are given in Table LXXVI. Of a total number of 14 larvæ, 8 attained full growth. Of these, 2 passed through five instars and 6 through six instars. A single larva (No. 8) that appeared stunted in its growth had seven instars, but failed to reach maturity. One full-grown larva of this brood wintered, while 7 resulted in moths the same year. Larvæ Nos. 11 to 14, inclusive, were left undisturbed during their early stages in order that their development should not be unduly delayed.

The observations on the molting habits of the second brood of larvæ (Table LXXVIII) were not all completed, as at times some of the larvæ were neglected on account of the stress of other work.

TABLE LXXX.—*Head measurements of first-brood and second-brood codling moth larvæ, collected from banded trees at Douglas, Mich., 1911.*

| No. of larvæ. | First brood larvæ. collected July 13. | No. of larvæ. | Second brood larvæ. collected Sept. 17. | No. of larvæ. | First brood larvæ. collected July 13. | No. of larvæ. | Second brood larvæ. collected Sept. 17. |
|---|---|---|---|---|---|---|---|
| | *mm.* | | *mm.* | | *mm.* | | *mm.* |
| 1 | 1.70♂ | 1 | 1.57♂ | 16 | 1.62♂ | 16 | 1.78♂ |
| 2 | 1.50♀ | 2 | 1.62♂ | 17 | 1.83♀ | 17 | 1.73♂ |
| 3 | 1.56♂ | 3 | 1.84♀ | 18 | 1.51♂ | 18 | 1.73♂ |
| 4 | 1.70♀ | 4 | 1.78♀ | 19 | 1.80♀ | 19 | 1.62♂ |
| 5 | 1.70♂ | 5 | 1.57♀ | 20 | 1.62♂ | 20 | 1.73♀ |
| 6 | 1.62♂ | 6 | 1.84♀ | 21 | 1.56♂ | 21 | 1.73♀ |
| 7 | 1.56♀ | 7 | 1.68♀ | 22 | 1.62♀ | 22 | 1.78♂ |
| [1] 8 | 1.29♀ | 8 | 1.62♂ | 23 | 1.67♀ | 23 | 1.78♂ |
| 9 | 1.62♀ | 9 | 1.78♀ | 24 | 1.62♂ | 24 | 1.62♂ |
| 10 | 1.70♂ | 10 | 1.84♀ | 25 | 1.70♀ | 25 | 1.89♀ |
| 11 | 1.79♂ | 11 | 1.68♂ | 26 | 1.70♂ | 26 | 1.78♀ |
| 12 | 1.56♀ | 12 | 1.68♂ | 27 | 1.62♂ | [1] 27 | 1.27♀ |
| 13 | 1.62♂ | 13 | 1.68♀ | 28 | 1.62♀ | 28 | 1.67♂ |
| 14 | 1.56♂ | [1] 14 | 1.29♀ | 29 | 1.80♀ | 29 | 1.67♀ |
| 15 | 1.56♀ | 15 | 1.73♀ | 30 | 1.65♀ | 30 | 1.89♂ |

[1] Parasitized larvæ.

The results from these observations are, however, similar to those previously obtained.

The pink color which is characteristic of the mature larva first appeared a few days after the final molt. A number of mature first and second brood larvæ collected in the field were measured for a comparison with those maturing in the laboratory. The records of Table LXXX show no material difference in the size of head of the larvæ of the two sets except that the field larvæ are slightly larger, which is to be expected, since the latter have developed normally and without any interference.

TABLE LXXXI.—*The average widths of the head of the larva in its successive instars and the rate of increase at each molt; summary of Tables LXXIV–LXXIX.*

| Instars. | 1910, second brood. | 1911, first brood. | 1911, second brood. | Average. | Average increase at each molt. |
|---|---|---|---|---|---|
| | *mm.* | *mm.* | *mm.* | *mm.* | *mm.* |
| First | 0.33 | 0.35 | 0.35 | 0.34 | 0.13 |
| Second | .48 | .47 | .47 | .47 | .20 |
| Third | .68 | .66 | .70 | .67 | .21 |
| Fourth | .94 | .89 | .81 | .88 | .30 |
| Fifth | 1.24 | 1.16 | 1.14 | 1.18 | .37 |
| Sixth | 1.54 | 1.47 | 1.63 | 1.55 | ........... |

The laboratory observations at Douglas, Mich., show that the number of molts of the codling moth may vary even under uniform conditions. The great majority, however, have six larval instars, a few only five, and very exceptionally seven instars.

Head measurements, when used in a series of consecutive tests, will bring out the number of molts of the larvæ, but this method can not be relied upon in determining the instars of any given larva, owing to the variability in size. The final averages as shown in Table LXXXI bring out the average widths of the head of the codling moth larva in its successive instars and also the rate of increase of each molt.

In 1881 Edwards[1] pointed out that the number of molts depends largely upon climatic conditions, these molts being more frequent in warm climates where the growth is rapid than in cold climates where the growth is retarded. The present records on the number of molts of the codling moth in Michigan and in the Ozarks corroborate Edwards's statement. Jenne found seven instars in the South, while in the North the writer found six instars.

### CANNIBALISM AMONG LARVÆ OF THE CODLING MOTH.

In confinement, when a large number of mature codling moth larvæ are kept together, it sometimes happens that certain larvæ will attack and kill weaker ones and later devour them. After such a feast the cannibal larva assumes a dull, turbid color and can be readily recognized from the rest. It is evident that cannibalism among the larvæ also takes place under normal conditions. It has frequently been noted that a number of newly hatched larvæ have entered the same apple, but only a single or a few larvæ matured in the same fruit. Occasionally larvæ have been collected from bands which had the characteristic appearance of cannibal larvæ.

### CODLING MOTH LARVÆ REMAINING TWO SEASONS IN THE LARVAL STAGE.

An unusual observation on the duration of the larval stage of the codling moth was made in 1909 and 1910 by Mr. R. W. Braucher at Douglas, Mich. In the fall of 1908 a number of larvæ were collected for rearing purposes and for studies to be made the following spring. Two of the larvæ failed to transform in 1909 and both were alive the following spring, 1910. On April 30 one larva had pupated; the other larva died June 24. The pupa, too, finally failed and was found dead July 18. Considering that the larva left the fruit about September 1, 1908, or possibly much earlier, we find that one of the insects remained 20 months in the larval stage without taking food or water and that the other specimen remained 23 months in the cocoon as larva and pupa. The two larvæ had made their cocoons in a large glass vial. They came under the writer's observation in 1910.

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[1] Psyche, vol. 3, p. 159,

The ability of an insect to remain dormant for a whole season and to transform subsequently the third season may possibly occur more frequently than has been actually observed. Such an adaptation would be of particular advantage to the species in surviving adverse seasons.

### CODLING MOTH LARVÆ FEEDING ON APPLE FOLIAGE.

To test the feeding habits of the codling moth larvæ on apple foliage three branches from which the fruit had been removed were bagged and on each 10 newly hatched larvæ were placed June 10. When examined July 20 it was found that in all three bags feeding had taken place, and particularly had the tender growths at the tips of the branches been eaten. In one of the bags, at the place where the same had been tied around the branch, one half-grown dead codling-moth larva was found in a cocoon. In one of the other bags one dead pupa was found, which was hardly two-thirds the average size. In the third bag no insect was found, though there was evidence of feeding. It may thus be suspected that in cases of total crop failures the insect can subsist on foliage in sufficient numbers for the perpetuation of the species.

### SUMMARY.

The present account of the life history of the codling moth in Michigan is based upon a series of studies made in 1909, 1910, and 1911.

In the course of a year the codling moth in Michigan produces one full brood and a partial second.

In the field the earliest moths of the spring brood commence to appear from 5 to 10 days after the apple blossoms drop, and the earliest larvæ of the first brood hatch from 3 to 4 weeks after the petals drop. The earliest larvæ of the second brood hatch from 10 to 11 weeks after the petals drop. During exceptionally warm and forward seasons the second-brood larvæ may appear considerably earlier, and were, in 1911, observed 8 weeks after the petals dropped. This record, however, should be considered very exceptional.

The time of appearance and the periods of occurrence of the different stages of the codling moth are shown in figure 11, which, with the exception of the spring pupal stage, closely represents the seasonal progress under average conditions. Figure 20 similarly shows this progress in the development of the insect under prevailing warm and exceptionally forward seasonal conditions.

Egg deposition commenced in the cages from 3 to 9 days after the emergence of the moths, and most of the eggs were laid within 5 days after egg deposition commenced. In one instance eggs were laid 23 days after the emergence of the moth, but as a rule the great majority of the eggs were laid within 8 days of the emergence.

The number of eggs per female varied considerably in the cages—on an average, 57 eggs per female were obtained. A single female deposited 161 eggs. Under normal conditions in the field the average number of eggs is unquestionably higher and probably approaches 80 to 90 eggs per female.

The average length of life of the moths was found to be 9 days for the males and 11 days for the females. Instances occurred when one male lived 32 days and a female lived 37 days.

The length of the incubation period of the eggs varied greatly under different temperature conditions. For the first brood the average length was 7 days and for the second brood 8 days. The range of variation extended from 4 to 16 days.

The effect of the temperature upon the length of the incubation period is shown by a plotted curve in figure 15.

The length of the feeding period of the larvæ of the first brood varied from 17 to 45 days and averaged 25 days for the "transforming" larvæ and 28 days for the "wintering" larvæ. Still larger variation in the length of feeding was observed in the second brood, ranging from 20 to 84 days and averaging 36 days.

On an average the larvæ spun their cocoons and pupated in 7 days. This period varied, however, from 3 to 18 days.

The pupal stage varied greatly under different temperature conditions, as is illustrated in figure 13. The average length of the pupal stage was 18 days and ranged from 1 week to 2 months.

The length of the first generation, from the time of the appearance of the eggs to the time of emergence of the moths that resulted from the same, averaged 51 days in 1910. During 1911 the duration of the life cycle varied from 29 to 87 days and averaged 50 days.

The relative abundance of first-brood and second-brood larvæ varied from year to year. In 1909 the second-brood larvæ surpassed the first brood in numbers and constituted 57 per cent of the larvæ for the season. During 1910, owing to the wide-felt scarcity of apples, the second brood only reached one-third the number of the first brood. During 1911 the second brood almost approached the first brood in abundance.

Of the first-brood larvæ only a portion transformed the same season, while the other portion passed the winter in the larval stage. During the three years of observation the ratio between transforming and wintering larvæ of the first brood varied from 30: 70 per cent to

51:49 per cent, respectively, and averaged 36 per cent transforming larvæ and 64 per cent wintering larvæ.

The larvæ of either brood shed the skin (molted) five times, and had thus six "instars." A limited number of larvæ molted only four times.

A hymenopterous fly, *Ascogaster carpocapsæ* Vier., was found to parasitize from 6 to 7 per cent of the larvæ of the codling moth.

Hibernating codling-moth larvæ succumb extensively to the cold during the winter. From 25 to 35 per cent were found to be killed.

From the foregoing records of the life history of the codling moth and from the variability of results obtained, it is evident that reliable data can only be obtained from a large number of observations.

From the point of view of mechanical control of the codling moth the most important observations of the habits of the insect relate to the time of emergence of the moths in the separate broods. Such observations should preferably be made from carefully conducted band records. It is essential that the collecting of larvæ from the banded trees should commence sufficiently early in the season so that the first-appearing larva may be secured. It is also of importance to make the collections at regular and frequent intervals (three days) and for the entire season. Apple trees of late varieties should be selected whenever available.

On applying the results of this investigation to the present methods of controlling the codling moth in Michigan it will be found that the poison-spray applications should be most effective when applied at the following periods:

*First.*—Shortly after the petals drop, to fill the open calyx cup and thus destroy the larvæ which hatch later. It is the habit of most of the first-brood larvæ to penetrate the apple through the calyx end.

*Second.*—From three to four weeks after the petals have dropped, when the first-brood larvæ commence to hatch.

*Third.*—Ten weeks after the petals have dropped, when under normal seasons the first larvæ of the second brood commence to appear. During advanced seasons the above period may be shortened to nine weeks and only very exceptionally to eight weeks, as noted in 1911.

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# PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

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## THE ONE-SPRAY METHOD IN THE CONTROL OF THE CODLING MOTH AND THE PLUM CURCULIO.

(Second Report.)

By

A. L. Quaintance, *In Charge of Deciduous Fruit Insect Investigations*,

and

E. W. Scott, *Entomological Assistant.*

### INTRODUCTION.

The present paper constitutes the second report on the "one-spray" method in the control of the codling moth in comparison with the usual demonstration treatment of from three to five applications according to locality. The previous report on this subject will be found in Bulletin 80, Part VII (Revised), pages 113 to 146 (1911) of the Bureau of Entomology. The experiments herewith reported are in continuation of those detailed in the publication cited, and have been done in connection with other experimental work at several of the bureau's field stations. In addition to the insect questions investigated in a given locality, attention has also been given to the control of certain diseases of the apple, this latter in cooperation with Mr. W. M. Scott, then of the Bureau of Plant Industry of this department. These tests have been made, as in the work previously reported, in widely separated States, representing a considerable range in climatic and other conditions, and were carried out as closely as possible according to a uniform plan, for the most part by different members of the force engaged in Deciduous Fruit Insect Investigations. The experiments in Virginia in 1910 were carried out by Messrs. J. W. Roberts and Leslie Pierce of the Bureau of Plant Industry and Messrs J. F. Zimmer and J. B. Gill of the Bureau of Entomology. The work in Michigan during 1911 was under the immediate direction of Mr. E. W. Scott, and in Delaware was done by Messrs. W. B. Wood and F. L. Simanton of the Bureau of Entomology and Mr. W. B. Middleton of the Bureau of Plant Industry. In Kansas, in 1911, the work was carried out by Mr. J. B. Gill of the Bureau of Entomology and Mr. Leslie Pierce of the Bureau of Plant Industry.

Since the appearance of the first report of the Bureau of Entomology on the one-spray method, additional information on the subject has been published by other workers, notably by Prof. W. E. Rumsey, in West Virginia Experiment Station Bulletin 127, and by Dr. E. P. Felt, in Circular 40 of the New York State Department of Agriculture and in the Journal of Economic Entomology for 1911 and for 1912. The information now available seems to warrant the conclusions given in the present paper.

## EXPERIMENTS IN VIRGINIA.

The experiments in Virginia were carried out during the season of 1910 in the orchard of Mr. W. F. Gilkeson near Fishersville. The entire orchard consists of 30 acres, but only about three-fourths of this was used for the experiments, the remainder being sprayed by the owner. The experimental part comprised three plats, as shown in the accompanying diagram (fig. 23). The trees of each plat from which the fruit was counted throughout the season for records are designated in the diagram by the same numbers which these trees bear in the table. The orchard is on a hillside gradually sloping to the southeast. It had a good cover crop of June grass and clover and was kept clean of dead limbs and rubbish, and the trees are headed rather low, thus facilitating spraying. The principal variety is York Imperial. There are a few Early Harvest trees scattered throughout the orchard, but none of these latter was included among the count trees. Plat I included 150 trees, Plat II 64 trees, and Plat III (the unsprayed plat) 10 trees, this last plat being in the center of the orchard. The treatments which the respective plats received are shown in Table I.

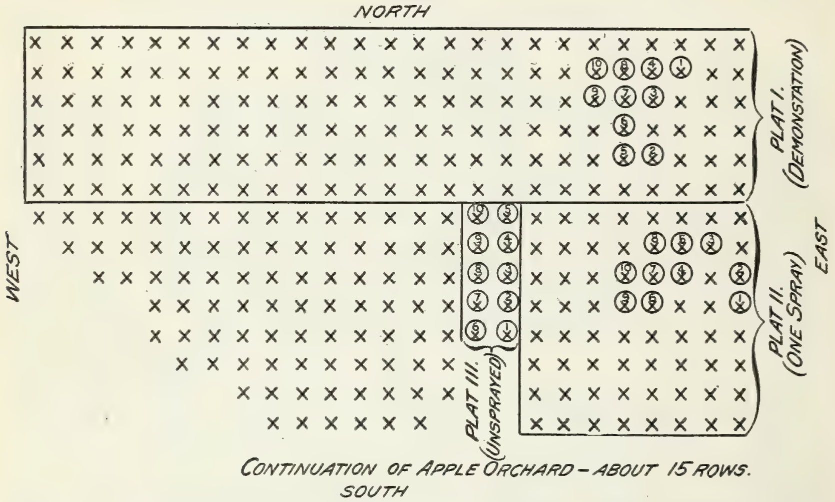

FIG. 23.—Diagram showing arrangement of plats and trees in the W. F. Gilkeson orchard, near Fishersville, Va. Trees counted are indicated by circles, the numbers agreeing with the numbers of trees in the tables. Variety, York Imperial. (Original.)

TABLE I.—*Treatments and dates of applications for the codling moth and the plum curculio. One-spray method. Fishersville, Va., 1910.*

| Dates of application. | Plat I. | Plat II. (One-spray method.) | Plat III. (Unsprayed.) |
|---|---|---|---|
| First application, Apr. 16–18 (as soon as petals fell). | Not drenched. Vermorel nozzles. Mist spray. Arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½–50). Pressure, 200 pounds. | Drenched with arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½–50). Bordeaux nozzles. Pressure, 200–225 pounds. | Unsprayed. |
| Second application, May 16 | do | Commercial lime-sulphur only (1½–50). Not drenched. No arsenical. | Do. |
| Third application, June 22 | do | do | Do. |

Plat I was sprayed thoroughly three times but was not drenched. Commercial lime-sulphur wash and arsenate of lead were used for each applicatoin. Plat II (one-spray method) was thoroughly drenched, Bordeaux nozzles and high pressure being used. This plat received one application of arsenate of lead and commercial lime-sulphur and two subsequent applications of commercial lime-sulphur only.

## THE CODLING MOTH.

In Table II is shown the total wormy fruit and fruit free from injury by the codling moth for the entire season for the eight count trees of each plat, the number of the trees in the figure agreeing with those in the table.

TABLE II.—*Number of sound and wormy apples for each tree from demonstration, one-spray and unsprayed plats. Fisherville, Va., 1910.*

PLAT I. LIME-SULPHUR DEMONSTRATION.

| Condition of fruit. | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Tree 7. | Tree 8. | Tree 9. | Tree 10. | Total for plat. | Total per cent of sound fruit. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wormy | 141 | 29 | 47 | 80 | 35 | 27 | 31 | 72 | 22 | 12 | 496 | ....... |
| Sound | 21,324 | 9,131 | 9,221 | 9,445 | 8,749 | 6,560 | 6,373 | 6,980 | 5,622 | 2,566 | 85,971 | ....... |
| Total | 21,465 | 9,160 | 9,268 | 9,525 | 8,784 | 6,587 | 6,404 | 7,052 | 5,644 | 2,578 | 86,467 | ....... |
| Per cent sound | 99.34 | 99.68 | 99.49 | 99.16 | 99.60 | 99.59 | 99.51 | 98.97 | 99.61 | 99.53 | ....... | 99.42 |

PLAT II. ONE-SPRAY METHOD.

| Condition of fruit. | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Tree 7. | Tree 8. | Tree 9. | Tree 10. | Total for plat. | Total per cent of sound fruit. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wormy | 82 | 88 | 63 | 63 | 6 | 29 | 33 | 77 | 41 | 23 | 505 | ....... |
| Sound | 7,282 | 6,543 | 8,044 | 7,539 | 2,023 | 3,372 | 3,777 | 5,873 | 3,065 | 3,127 | 50,645 | ....... |
| Total | 7,364 | 6,631 | 8,107 | 7,602 | 2,029 | 3,401 | 3,810 | 5,950 | 3,106 | 3,150 | 51,150 | ....... |
| Per cent sound | 98.88 | 98.67 | 99.22 | 99.17 | 99.70 | 99.14 | 99.13 | 98.70 | 99.68 | 99.27 | ....... | 99.01 |

PLAT III. UNSPRAYED.

| Condition of fruit. | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Tree 7. | Tree 8. | Tree 9. | Tree 10. | Total for plat. | Total per cent of sound fruit. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wormy | 781 | 423 | 487 | 480 | 355 | 296 | 812 | 188 | 421 | 776 | 5,019 | ....... |
| Sound | 5,159 | 1,908 | 3,067 | 2,935 | 1,874 | 1,329 | 4,413 | 1,168 | 2,285 | 3,227 | 27,365 | ....... |
| Total | 5,940 | 2,331 | 3,554 | 3,415 | 2,229 | 1,625 | 5,225 | 1,356 | 2,706 | 4,003 | 32,384 | ....... |
| Per cent sound | 86.85 | 81.84 | 86.29 | 85.94 | 84.07 | 81.78 | 84.45 | 86.13 | 84.44 | 80.61 | ....... | 84.50 |

Plat I, which received all three applications of arsenate of lead, gave 99.42 per cent fruit free from codling-moth injury, the percentage for individual trees ranging from 98.97 to 99.68. The total number of apples counted from this plat was 86,467. Plat II received the one-spray treatment and shows a total of 99.01 per cent of fruit free from codling-moth injury, the percentages for individual trees ranging from 98.67 to 99.70, and the total number of apples examined being 51,150. This shows a difference of only 0.41 per cent in favor of the demonstration. Plat III, the unsprayed plat, shows 84.50 per cent fruit free from codling-moth injury, the total number of apples examined being 32,384. This shows a gain in sound fruit by the demonstration treatment of 14.92 per cent, and by the one-spray method a gain of 14.51. As will be noted, the percentages of sound fruit from the check trees is rather high. This is probably very largely due to the fact that these were located in the center of the orchard, all the surrounding trees being sprayed.

In Table III are shown the places of entrance into the apple of the total larvæ for the season for each tree of each plat, and also the percentage, by plats, entering the fruit at the calyx, side, and stem.

There was a total of 496 larvæ on the demonstration plat, as against 505 larvæ on the one-spray plat, a difference of only 9 larvæ in favor of the demonstration plat. On the unsprayed plat there was a total of 5,019 larvæ. Comparing the percentages of larvæ entering at the calyx end of the apple on the different plats it will be noted that the demonstration plat shows 33.06 per cent entering at the calyx end as compared with 13.46 per cent on the one-spray plat. The unsprayed plat shows 63.86 per cent of larvæ entering at this point, which may be taken to indicate the normal behavior of the larvæ.

Table IV shows the comparative efficiency of the demonstration and one-spray treatments in preventing infestation at calyx, side, and stem.

By comparing the figures for the different plats it will be seen that the one-spray treatment was more effective than the demonstration in preventing entrance at the calyx, and less effective in preventing entrance at the side and stem. The demonstration treatment saved a total of only 0.41 per cent more of the crop than the one-spray method, most of this saving being due to prevention of side entrances.

TABLE III.—*Places of entrance of fruit by total larvæ of the codling moth for each tree of each plat. Fishersville, Va., 1910.*

| Total number of larvæ and place of entrance of fruit for each tree, first and second broods combined. | | | | | | | | | | | Total for plats. | Percentage of larvæ entering at calyx, side, and stem. | Total number of larvæ. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Place of entrance. | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Tree 7. | Tree 8. | Tree 9. | Tree 10. | | | |
| PLAT I. LIME-SULPHUR DEMONSTRATION. | | | | | | | | | | | | | |
| First and second broods: | | | | | | | | | | | | | |
| Calyx | 49 | 6 | 14 | 25 | 5 | 10 | 16 | 32 | 4 | 3 | 164 | 33.06 | ....... |
| Side | 60 | 20 | 26 | 40 | 22 | 12 | 11 | 14 | 12 | 9 | 226 | 45.57 | ....... |
| Stem | 32 | 3 | 7 | 15 | 8 | 5 | 4 | 26 | 6 | 0 | 106 | 21.37 | ....... |
| Total | 141 | 29 | 47 | 80 | 35 | 27 | 31 | 72 | 22 | 12 | 496 | 100.00 | 496 |
| PLAT II. ONE-SPRAY METHOD. | | | | | | | | | | | | | |
| First and second broods: | | | | | | | | | | | | | |
| Calyx | 8 | 11 | 6 | 7 | 1 | 4 | 12 | 11 | 4 | 4 | 68 | 13.46 | ....... |
| Side | 45 | 49 | 42 | 30 | 4 | 14 | 17 | 40 | 26 | 13 | 280 | 55.45 | ....... |
| Stem | 29 | 28 | 15 | 26 | 1 | 11 | 4 | 26 | 11 | 6 | 157 | 31.09 | ....... |
| Total | 82 | 88 | 63 | 63 | 6 | 29 | 33 | 77 | 41 | 23 | 505 | 100.00 | 505 |
| PLAT III. UNSPRAYED. | | | | | | | | | | | | | |
| First and second broods: | | | | | | | | | | | | | |
| Calyx | 487 | 252 | 297 | 296 | 244 | 196 | 561 | 111 | 251 | 510 | 3,205 | 63.86 | ....... |
| Side | 132 | 78 | 88 | 100 | 60 | 58 | 93 | 43 | 62 | 105 | 819 | 16.32 | ....... |
| Stem | 162 | 93 | 102 | 84 | 51 | 42 | 158 | 34 | 108 | 161 | 995 | 19.82 | ....... |
| Total | 781 | 423 | 487 | 480 | 355 | 296 | 812 | 188 | 421 | 776 | 5,019 | 100.00 | 5,019 |

TABLE IV.—*Efficiency of the demonstration and one-spray treatments as shown by the percentage of wormy apples. Fishersville, Va., 1910.*

| Plat No. | Percentage of wormy apples. | | | | Total number of wormy apples. | Total number of apples. |
|---|---|---|---|---|---|---|
| | Calyx. | Side. | Stem. | Total. | | |
| I. Demonstration | 0.19 | 0.26 | 0.12 | 0.57 | 496 | 86,467 |
| II. One spray | .13 | .54 | .31 | .98 | 505 | 51,150 |
| III. Unsprayed | 9.89 | 2.53 | 3.07 | 15.49 | 5,019 | 32,384 |

## THE PLUM CURCULIO.

Table V shows the effect of the treatments in the W. F. Gilkeson orchard in controlling the plum curculio on the three plats. Egg and feeding punctures are combined in the table under "Number of punctures."

TABLE V.—*Injury by the plum curculio for entire season. Plats I, II, and III. Fishersville, Va., 1910.*

PLAT I. LIME-SULPHUR DEMONSTRATION.

| Number of punctured and sound apples, etc., per tree in each plat. | | | | | | | | | | | Total for plat. | Total per cent of of fruit free from injury. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Tree 7. | Tree 8. | Tree 9. | Tree 10. | | |
| Number punctures | 1,333 | 677 | 618 | 747 | 864 | 757 | 835 | 819 | 369 | 210 | 7,229 | ........ |
| Number fruit punctured | 987 | 321 | 397 | 471 | 522 | 483 | 476 | 542 | 239 | 123 | 4,561 | ........ |
| Number sound fruit | 20,478 | 8,839 | 8,871 | 9,054 | 8,262 | 6,104 | 5,928 | 6,510 | 5,405 | 2,455 | 81,906 | ........ |
| Number fruit | 21,465 | 9,160 | 9,268 | 9,525 | 8,784 | 6,587 | 6,404 | 7,052 | 5,644 | 2,578 | 86,467 | ........ |
| Per cent free from injury | 95.40 | 96.49 | 95.71 | 95.05 | 94.05 | 92.66 | 92.56 | 92.31 | 95.76 | 95.22 | ........ | 94.72 |

PLAT II. ONE-SPRAY METHOD.

| | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Tree 7. | Tree 8. | Tree 9. | Tree 10. | Total for plat. | Total per cent of of fruit free from injury. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number punctures | 855 | 1,025 | 563 | 744 | 113 | 271 | 231 | 314 | 149 | 223 | 4,488 | ........ |
| Number fruit punctured | 428 | 584 | 544 | 516 | 107 | 156 | 143 | 202 | 90 | 112 | 2,882 | ........ |
| Number sound fruit | 6,936 | 6,140 | 7,563 | 7,086 | 1,918 | 3,245 | 3,667 | 5,748 | 3,015 | 3,037 | 48,355 | ........ |
| Number fruit | 7,364 | 6,724 | 8,107 | 7,602 | 2,025 | 3,401 | 3,810 | 5,950 | 3,105 | 3,149 | 51,237 | ........ |
| Per cent free from injury | 94.20 | 91.31 | 93.28 | 93.21 | 94.71 | 95.41 | 96.24 | 96.60 | 97.10 | 96.44 | ........ | 94.37 |

PLAT III. UNSPRAYED.

| | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Tree 7. | Tree 8. | Tree 9. | Tree 10. | Total for plat. | Total per cent of of fruit free from injury. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number punctures | 917 | 311 | 332 | 483 | 231 | 168 | 683 | 146 | 342 | 620 | 4,233 | ........ |
| Number fruit punctured | 673 | 246 | 297 | 344 | 165 | 128 | 463 | 81 | 283 | 434 | 3,114 | ........ |
| Number sound fruit | 5,267 | 2,085 | 3,257 | 3,071 | 2,064 | 1,497 | 4,762 | 1,275 | 2,423 | 3,569 | 29,270 | ........ |
| Number fruit | 5,940 | 2,331 | 3,554 | 3,415 | 2,229 | 1,625 | 5,225 | 1,356 | 2,706 | 4,003 | 32,384 | ........ |
| Per cent free from injury | 88.67 | 89.44 | 91.64 | 89.92 | 92.59 | 92.12 | 91.13 | 94.02 | 89.54 | 89.15 | ........ | 90.38 |

On the demonstration plat the percentage of fruit uninjured by the curculio was 94.72, and on the one-spray plat 94.37, which shows only 0.35 per cent in favor of the demonstration plat. The unsprayed plat shows 90.38 per cent free from curculio injury. As has been noted, the check trees were in the center of the orchard and surrounded by sprayed trees, which no doubt accounts largely for the high percentage of sound fruit on the check plat.

## EXPERIMENTS IN MICHIGAN.

The experiments in Michigan during the season of 1911 were carried out in Mr. Edward Hutchins's orchard near Fennville, Mich. The entire orchard, consisting of 205 trees, was used for the experimental and demonstration spraying, the experimental part being located in the western portion of the orchard where the principal varieties are Baldwin and Rhode Island Greening. The plats were laid off across these varieties in order to have both represented in each plat. (See fig. 24.) The east side of the orchard is composed of a general mixture of many varieties. Trees of each plat from which the fruit was counted throughout the season for records are designated by the same numbers which these trees bear in the tables. The orchard is almost level, sloping slightly toward the west. It was kept clean, cultivated throughout the summer, and sown to oats in the fall for cover crop. The trees are 30 years old and medium to large in size. Plat I included 18 trees; Plat II, 17 trees; Plat III, 19 trees; Plat IV, 12 trees; Plat V (the unsprayed plat), 21 trees, this last plat extending across the orchard near the center. The treatments given and dates of application are shown in Table VI.

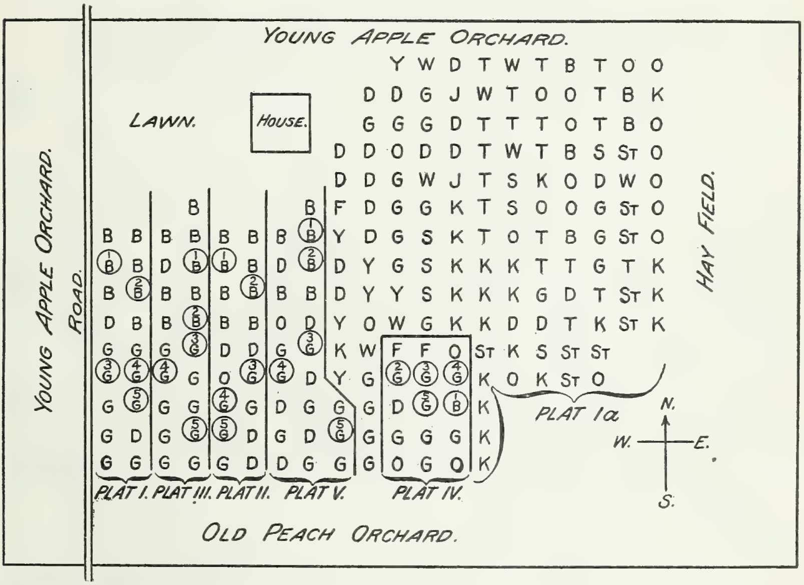

FIG. 24.—Diagram showing arrangement of plats and trees in the Edward Hutchins orchard, near Fennville, Mich. Trees counted are indicated by circles, the numbers agreeing with the numbers of trees in the tables. Varieties: *B*, Baldwin; *G*, Rhode Island Greening (counts were made from these first two varieties only); *D*, Dutchess; *Y*, Yellow Transparent; *K*, King; *F*, Fall Pippin; *St*, Stark; *S*, Sweet Greening; *W*, Wagner; *T*, Tolman Sweet; *J*, Jersey Sweet. (Original.)

TABLE VI.—*Treatments and dates of application for the codling moth and the plum curculio. One-spray method, etc. Fennville, Mich., 1911.*

| Dates of application. | Plat I. | Plat II. | Plat III. (One-spray method.) |
|---|---|---|---|
| First application, May 12 (after cluster buds open.) | Scab treatment. Commercial lime-sulphur (1½–50) alone. | Scab treatment. Home-boiled lime-sulphur (4S–2L–50) alone. | Scab treatment. Commercial lime-sulphur (1½–50) alone. |
| Second application, May 25 (as soon as petals dropped). | Not drenched. Mist nozzles. Arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½–50). Pressure, 125 pounds. | Not drenched. Mist nozzles. Arsenate of lead, 2 pounds to 50 gallons home-boiled lime-sulphur (4S–2L–50). Pressure, 125 pounds. | Drenched with arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½–50). Bordeaux nozzles. Pressure, 150–175 pounds. |
| Third application, June 14. | .....do..... | .....do..... | Commercial lime-sulphur only (1½–50). Not drenched. |
| Fourth application, July 25. | .....do..... | .....do..... | Do. |

TABLE VI.—*Treatments and dates of application for the codling moth and the plum curculio. One-spray method, etc. Fennville, Mich., 1911*—Continued.

| Dates of application. | Plat IV. | Plat V. (Unsprayed.) |
|---|---|---|
| First application, May 12 (after cluster buds open). | Scab treatment. Bordeaux (4-4-50) alone | Unsprayed.) |
| Second application, May 25 (as soon as petals dropped). | Not drenched. Mist nozzles. Arsenate of lead, 2 pounds to 50 gallons Bordeaux (4-4-50). Pressure, 125 pounds. | Do. |
| Third application, June 14 | do | Do. |
| Fourth application, July 25 | do | Do. |

All of the sprayed plats received an early application when the cluster buds opened for control of scab. No arsenate of lead was used with this application. Plats I, II, and IV received three subsequent treatments in which arsenate of lead was used with each treatment at the rate of 2 pounds to 50 gallons, the only difference in treatments of these three plats being that on Plat I the lead was used with commercial lime-sulphur, on Plat II with home-boiled lime-sulphur, and on Plat IV with Bordeaux. Mist or Vermorel nozzles were used for spraying these plats and a pressure of about 125 pounds was carried. The trees were given a thorough spraying. Plat III, the one-spray plat, was thoroughly drenched during the second application, the only application in which arsenate of lead was used on this plat. A pressure of about 150 pounds was carried, and Bordeaux nozzles were used, giving a coarse, driving spray. This plat received for this application an average of 16 gallons per tree as against 14 gallons per tree for the same application on the other plats.

The dropped fruit was picked up from under the count trees about every 10 days throughout the season and carefully examined as to codling-moth and curculio injury. The fruit picked from the tree in the fall was examined in the same way, and the results presented include all the dropped fruit and the fruit picked from the tree.

## THE CODLING MOTH.

In Table VII are shown the results of treatment of all the plats as to injury from the codling moth, these results being obtained from three Rhode Island Greening trees of each plat. The numbers of the trees in the table agree with those in the diagram of the orchard (fig. 24).

TABLE VII.—*Number of sound and wormy apples for each tree from commercial lime-sulphur, home-boiled sulphur, Bordeaux, one-spray method, and unsprayed plats. Fennville, Mich., 1911.*

| Condition of fruit. | Tree 3. | Tree 4. | Tree 5. | Total for plat. | Total per cent of sound fruit. |
|---|---|---|---|---|---|
| PLAT I. COMMERCIAL LIME-SULPHUR DEMONSTRATION. | | | | | |
| Wormy | 154 | 85 | 32 | 271 | |
| Sound | 1,914 | 946 | 694 | 3,554 | |
| Total | 2,068 | 1,031 | 726 | 3,825 | |
| Per cent sound | 92.55 | 91.75 | 95.59 | | 92.91 |
| PLAT II. HOME-BOILED LIME-SULPHUR DEMONSTRATION. | | | | | |
| Wormy | 84 | 76 | 88 | 248 | |
| Sound | 1,899 | 2,702 | 1,862 | 6,463 | |
| Total | 1,983 | 2,778 | 1,950 | 6,711 | |
| Per cent sound | 95.76 | 97.26 | 95.48 | | 96.30 |
| PLAT III. ONE-SPRAY METHOD. | | | | | |
| Wormy | 50 | 510 | 123 | 683 | |
| Sound | 606 | 2,494 | 1,492 | 4,592 | |
| Total | 656 | 3,004 | 1,615 | 5,275 | |
| Per cent sound | 92.37 | 83.02 | 92.38 | | 87.05 |
| PLAT IV. BORDEAUX-MIXTURE DEMONSTRATION. | | | | | |
| Wormy | 12 | 146 | 23 | 181 | |
| Sound | 684 | 2,157 | 1,119 | 3,960 | |
| Total | 696 | 2,303 | 1,142 | 4,141 | |
| Per cent sound | 98.27 | 93.66 | 97.98 | | 95.62 |
| PLAT V. UNSPRAYED. | | | | | |
| Wormy | 766 | 1,013 | 1,302 | 3,081 | |
| Sound | 901 | 1,468 | 1,062 | 3,437 | |
| Total | 1,667 | 2,481 | 2,370 | 6,518 | |
| Per cent sound | 54.04 | 59.16 | 44.81 | | 52.73 |

As will be seen from the foregoing table, there were counted from Plats I, II, III, IV, and V, respectively, 3,825, 6,711, 5,275, 4,141, and 6,518 apples, a total for all plats of 26,470. (In giving the results from all of the other one-spray experiments presented in this paper the one-spray plat is compared with the commercial lime-sulphur demonstration; therefore, for sake of uniformity, the same comparison is made in this experiment.) Plat I, which received the commercial lime-sulphur treatment, shows for the individual trees a range in percentage of fruit free from the codling moth of 91.75 to

95.59, with a total for all trees of 92.91, as against a total of 87.05 per cent free from this insect in Plat III, the one-spray plat, a difference in favor of Plat I of 5.86 per cent. The range for individual trees in Plat III was 83.02 to 92.38. Plat V, the unsprayed plat, shows a total percentage of 52.73 of fruit free from the codling moth, the range being from 44.81 to 59.16. There is thus a gain over the unsprayed fruit in sound fruit by the demonstration treatment of 40.18 per cent and by the one-spray method a gain of 34.32 per cent of sound fruit. (See Pl. IV, figs. 1, 2, 3.)

Plat II, which received the home-boiled lime-sulphur demonstration treatment, shows a total percentage of fruit free from injury of 96.30, and Plat IV, the Bordeaux demonstration plat, shows 95.62 per cent of fruit free from injury.

In Table VIII are shown the places of entrance of the fruit for each tree of each plat for the total larvæ throughout the season.

TABLE VIII.—*Places of entrance of fruit by total larvæ of the codling moth for each tree of each plat. Fennville, Mich., 1911.*

PLAT I. COMMERCIAL LIME-SULPHUR DEMONSTRATION.

| Total number of larvæ and place of entrance of fruit for each tree; first and second broods combined. | | | | Total for plat. | Percentage of larvæ entering at calyx, side, and stem. | Total number of larvæ. |
|---|---|---|---|---|---|---|
| Place of entrance. | Tree 3. | Tree 4. | Tree 5. | | | |
| First and second broods: | | | | | | |
| Calyx | 12 | 21 | 8 | 41 | 13.62 | .......... |
| Side | 164 | 64 | 26 | 254 | 84.39 | .......... |
| Stem | 2 | 3 | 1 | 6 | 1.99 | .......... |
| Total | 178 | 88 | 35 | 301 | 100.00 | 301 |

PLAT II. HOME-BOILED LIME-SULPHUR DEMONSTRATION.

| | | | | | | |
|---|---|---|---|---|---|---|
| First and second broods: | | | | | | |
| Calyx | 6 | 7 | 6 | 19 | 6.15 | .......... |
| Side | 102 | 79 | 104 | 285 | 92.23 | .......... |
| Stem | 2 | 2 | 1 | 5 | 1.62 | .......... |
| Total | 110 | 88 | 111 | 309 | 100.00 | 309 |

PLAT III. ONE-SPRAY METHOD.

| | | | | | | |
|---|---|---|---|---|---|---|
| First and second broods: | | | | | | |
| Calyx | 4 | 54 | 7 | 65 | 6.65 | .......... |
| Side | 65 | 661 | 153 | 879 | 89.97 | .......... |
| Stem | 4 | 24 | 5 | 33 | 3.38 | .......... |
| Total | 73 | 739 | 165 | 977 | 100.00 | 977 |

PLAT IV. BORDEAUX-MIXTURE DEMONSTRATION.

| | | | | | | |
|---|---|---|---|---|---|---|
| First and second broods: | | | | | | |
| Calyx | 3 | 47 | 5 | 55 | 27.64 | .......... |
| Side | 8 | 109 | 19 | 136 | 68.34 | .......... |
| Stem | 1 | 5 | 2 | 8 | 4.02 | .......... |
| Total | 12 | 161 | 26 | 199 | 100.00 | 199 |

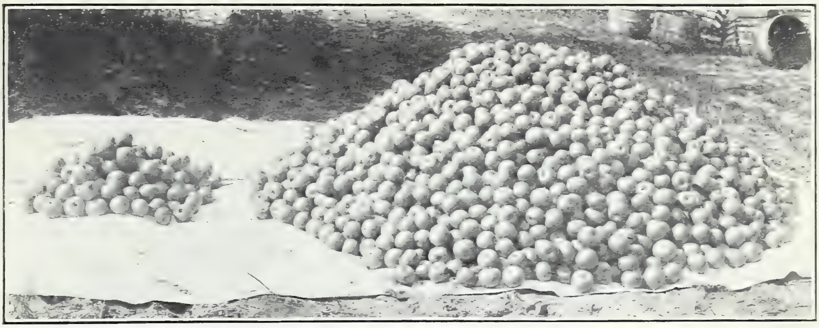

FIG. 1.—PICKED APPLES FROM THREE TREES OF PLAT I (DEMONSTRATION) IN THE EDWARD HUTCHINS ORCHARD, FENNVILLE, MICH. SOUND FRUIT ON THE RIGHT; WORMY FRUIT ON THE LEFT. (ORIGINAL.)

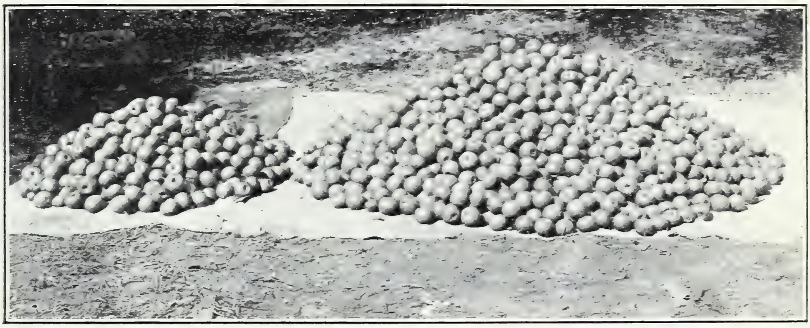

FIG. 2.—PICKED APPLES FROM THREE TREES OF PLAT III (ONE-SPRAY) IN THE EDWARD HUTCHINS ORCHARD, FENNVILLE, MICH. SOUND FRUIT ON THE RIGHT; WORMY FRUIT ON THE LEFT. (ORIGINAL.)

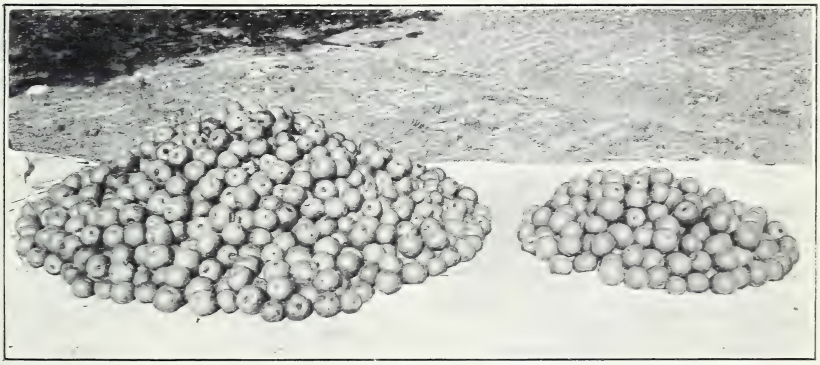

FIG. 3.—PICKED APPLES FROM THREE TREES OF PLAT V (UNSPRAYED) IN THE EDWARD HUTCHINS ORCHARD, FENNVILLE, MICH. SOUND FRUIT ON THE RIGHT; WORMY FRUIT ON THE LEFT. (ORIGINAL.

TABLE VIII.—*Places of entrance of fruit by total larvæ of the codling moth for each tree of each plat. Fennville, Mich., 1911*—Continued.

PLAT V. UNSPRAYED.

| Total number of larvæ and place of entrance of fruit for each tree; first and second broods combined. | | | | Total for plat. | Percentage of larvæ entering at calyx, side, and stem. | Total number of larvæ. |
|---|---|---|---|---|---|---|
| Place of entrance. | Tree 3. | Tree 4. | Tree 5. | | | |
| First and second broods: | | | | | | |
| Calyx | 577 | 856 | 1,022 | 2,455 | 54.21 | .......... |
| Side | 553 | 574 | 593 | 1,720 | 37.98 | .......... |
| Stem | 99 | 139 | 116 | 354 | 7.81 | .......... |
| Total | 1,229 | 1,569 | 1,731 | 4,529 | 100.00 | 4,529 |

As shown in the above table, the total number of larvæ on Plats I, III, and V were 301, 977, and 4,529, respectively. The unsprayed plat (Plat V) may be taken to indicate the normal behavior of the larvæ and shows that 54.21 per cent of the total larvæ of both broods entered the calyx end of the apples. In case of the sprayed plats, as would be expected, the proportion entering at the calyx is greatly reduced, and there is a corresponding increase in the proportion entering the fruit at the side and stem. The demonstration plat shows 13.62 per cent of total larvæ entering at the calyx end as compared with 6.65 per cent in the one-spray plat. Comparing the percentage of larvæ entering at the stem end of the apple it will be noted that this percentage on Plat I is 1.99, as compared with 3.38 per cent on the one-spray plat. It would be expected that this difference would be due to the protection of the stem end of the apple by the later applications of poison on the demonstration plat, and this is probably a correct conclusion. However, by referring to the foregoing table it will be seen that in the case of Plat IV, the Bordeaux-demonstration plat, 4.02 per cent of larvæ entered at the stem end.

The efficiency of the one-spray and demonstration treatments in preventing worminess is shown in condensed form in Table IX.

TABLE IX.—*Efficiency of the demonstration and one-spray treatments as shown by the percentage of wormy apples. Fennville, Mich., 1911.*

| Plat No. | Percentage of wormy apples.[1] | | | | Total number of wormy apples. | Total number of apples. |
|---|---|---|---|---|---|---|
| | Calyx. | Side. | Stem. | Total. | | |
| I. Demonstration | 0.96 | 5.98 | 0.14 | 7.08 | 271 | 3,825 |
| III. One-spray | .86 | 11.64 | .44 | 12.94 | 683 | 5,275 |
| V. Unsprayed | 25.62 | 17.95 | 3.69 | 47.26 | 3,081 | 6,518 |

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[1] Each entrance was counted in determining the percentages for calyx, side, and stem, so that the sum of these percentages exceeds the total percentages of wormy fruit.

Here, as in the foregoing experiment, the one-spray treatment was more efficient than the demonstration treatment in preventing entrance at the calyx, the difference being 0.10 per cent in favor of the one-spray treatment. However, the one-spray treatment afforded only about one-half as much protection as the demonstration treatment against side worminess. In comparing the total efficiency of the two treatments it will be seen that there was a saving of 40.18 per cent of the crop in Plat I and of 34.32 per cent in Plat III.

## EXPERIMENTS IN DELAWARE.

The experiments in Delaware in 1911 were carried out in the orchard of F. C. Bancroft, near Camden, Del. The part of the orchard used for this experiment was a block of about 600 trees somewhat isolated from the rest of the apple orchard. On the north side was a peach orchard, on the east and south a pear orchard, and on the west a cornfield. The orchard was almost level, having just enough slope to drain well. It was well tilled throughout the season. The main variety was Stayman Winesap, with Missouri Pippin used as the principal filler. The trees were 16 years old and were rather large for their age. The plats were laid out diagonally across the orchard, as shown in the accompanying diagram (fig. 25). Trees of each plat from which the fruit was counted throughout the season for records are designated in the diagram by the same numbers which these trees bear in the table. Plat II includes 60 trees; Plat III, 52 trees; Plat VII, 39 trees, and Plat VIII, 25 trees. The treatments to which the respective plats were subjected are shown in Table X.

TABLE X.—*Treatments and dates of application for the codling moth and the plum curculio. One-spray method. Camden, Del., 1911.*

| Dates of application. | Plat II. (Demonstration.) Commercial lime-sulphur and arsenate of lead. | Plat VII. (One-spray method.) Commercial lime-sulphur and arsenate of lead. | Plat VIII. (Unsprayed.) |
|---|---|---|---|
| First application, Apr. 27 (before blossoms opened). | Scab treatment. Mist spray. Commercial lime-sulphur (1¼–50) plus 2 pounds of arsenate of lead. Pressure, 140 pounds. | Scab treatment. Mist spray. Commercial lime-sulphur alone (1½–50). Pressure, 140 pounds. | Unsprayed. |
| Second application, May 13 and 15 (after petals dropped). | Not drenched. Mist nozzles used. Arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur. Pressure, 140 pounds. | Drenched with arsenate of lead, 2 pounds to 50 gallons of commercial lime-sulphur (1¼–50). Coarse spray. Bordeaux nozzles. Pressure, 140–150 pounds. | Do. |
| Third application, June 7 | .....do | Commercial lime-sulphur alone (1½–50). Not drenched. | Do. |
| Fourth application, July 10. | .....do | .....do | Do. |

Both sprayed plats received four applications in all, the first before blooming, but after cluster buds had opened, to protect the fruit from apple scab. Plat II received arsenate of lead at the rate of 2 pounds to 50 gallons of lime-sulphur for each application. Plat VII, the one-spray plat, received the arsenate-of-lead treatment only for the second application, which was made immediately after the falling of the petals. Both plats were thoroughly sprayed but not drenched, except at the time of the second application, when the one-spray plat was drenched, for which purpose Bordeaux nozzles were used, the demonstration plat being sprayed as usual with mist nozzles. Plat VIII was left unsprayed throughout.

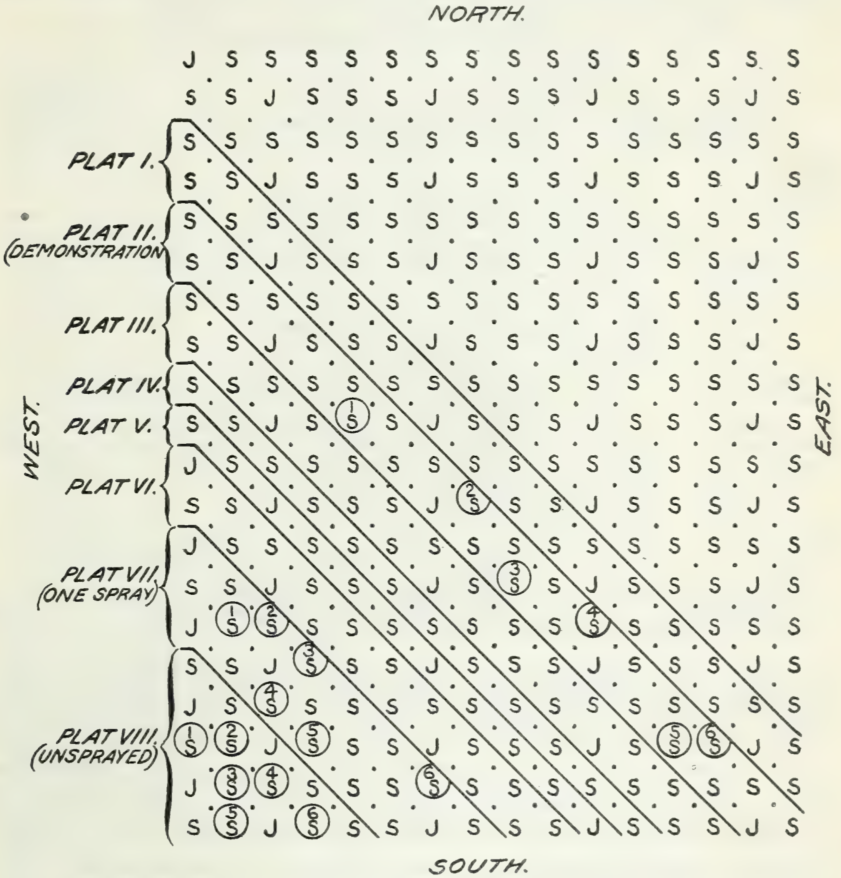
NORTH.
PLAT I.
PLAT II.
(DEMONSTRATION)
PLAT III.
PLAT IV.
PLAT V.
PLAT VI.
PLAT VII.
(ONE SPRAY)
PLAT VIII.
(UNSPRAYED)
WEST.
EAST.
SOUTH.

FIG. 25.—Diagram showing arrangement of plats and trees in the F. C. Bancroft orchard, near Camden, Del.: *S*, Stayman; *J*, Jonathan; (.), Mixed varieties used as fillers. Count trees are indicated by circles, the numbers agreeing with those in the tables. (Original.)

## THE CODLING MOTH.

In Table XI are shown results of treatments on Plats II and VII as compared with Plat VIII (the unsprayed plat) as to injury from the codling moth.

TABLE XI.—*Number of sound and wormy apples from each tree from demonstration, one-spray, and unsprayed plats. Camden, Del., 1911.*

| Condition of fruit. | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Total for plat. | Total per cent of sound fruit. |
|---|---|---|---|---|---|---|---|---|
| PLAT II. LIME-SULPHUR DEMONSTRATION. | | | | | | | | |
| Wormy | 27 | 42 | 35 | 11 | 26 | 6 | 147 | |
| Sound | 3,655 | 2,365 | 3,737 | 2,693 | 4,751 | 2,720 | 19,921 | |
| Total | 3,682 | 2,407 | 3,772 | 2,704 | 4,777 | 2,726 | 20,068 | |
| Per cent sound | 99.26 | 98.25 | 99.07 | 99.59 | 99.45 | 99.77 | | 99.27 |
| PLAT VII. ONE-SPRAY METHOD. | | | | | | | | |
| Wormy | 237 | 210 | 121 | 284 | 187 | 264 | 1,303 | |
| Sound | 2,327 | 1,884 | 2,696 | 4,240 | 2,906 | 2,828 | 16,881 | |
| Total | 2,564 | 2,094 | 2,817 | 4,524 | 3,093 | 3,092 | 18,184 | |
| Per cent sound | 90.75 | 89.97 | 95.70 | 93.72 | 93.95 | 91.46 | | 92.83 |
| PLAT VIII. UNSPRAYED. | | | | | | | | |
| Wormy | 2,064 | 2,427 | 1,509 | 1,761 | 2,465 | 1,555 | 11,781 | |
| Sound | 1,404 | 2,471 | 1,712 | 962 | 1,678 | 806 | 9,033 | |
| Total | 3,468 | 4,898 | 3,221 | 2,723 | 4,143 | 2,361 | 20,814 | |
| Per cent sound | 40.48 | 50.44 | 53.15 | 35.32 | 40.50 | 34.13 | | 43.40 |

The total percentage of fruit free from codling-moth injury on the demonstration plat was 99.27, the range in percentage for individual trees being from 98.25 to 99.77. On the one-spray plat the total percentage free from this insect was 92.83, the range in percentage for the individual trees being from 89.97 to 95.70. The unsprayed plat shows only 43.40 per cent free from codling moth, with a range in percentage for individual trees of from 34.13 to 53.15. The demonstration plat shows an increase of sound fruit over the one-spray method of 6.44 per cent and over the unsprayed plat of 55.87 per cent. The one-spray plat shows an increase of sound fruit over the unsprayed plat of 49.43 per cent. The number of apples counted on the respective plats were 20,068, 18,184, and 20,814, giving a total of 59,066 for the three plats. By referring to the diagram of the orchard (fig. 25) it will be noted that the one-spray plat adjoined the unsprayed plat on the southwest side, which would tend to lower the efficiency of the spray owing to the migration of the moths from the unsprayed plat during the season.

Table XII gives the places of entrance of the fruit for each tree of each plat for the total larvæ of the two broods throughout the season.

TABLE XII.—*Places of entrance of fruit by total larvæ of the codling moth for each tree of each plat. Camden, Del., 1911.*

PLAT II. LIME-SULPHUR DEMONSTRATION.

| Total number of larvæ and place of entrance of fruit for each tree, first and second broods combined. | | | | | | | Total for plat. | Percentage of larvæ entering at calyx, side, and stem. | Total number of larvæ. |
|---|---|---|---|---|---|---|---|---|---|
| Place of entrance. | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | | | |
| First and second broods: | | | | | | | | | |
| Calyx | 3 | 0 | 1 | 1 | 1 | 0 | 6 | 4.08 | .......... |
| Side | 22 | 39 | 31 | 6 | 22 | 5 | 125 | 85.03 | .......... |
| Stem | 2 | 3 | 3 | 4 | 3 | 1 | 16 | 10.89 | .......... |
| Total | 27 | 42 | 35 | 11 | 25 | 6 | 147 | 100.00 | 147 |
| PLAT VII. ONE-SPRAY METHOD. | | | | | | | | | |
| First and second broods: | | | | | | | | | |
| Calyx | 14 | 14 | 6 | 10 | 8 | 13 | 65 | 4.99 | .......... |
| Side | 199 | 169 | 99 | 238 | 164 | 216 | 1,085 | 83.27 | .......... |
| Stem | 24 | 27 | 16 | 36 | 15 | 35 | 153 | 11.74 | .......... |
| Total | 237 | 210 | 121 | 284 | 187 | 264 | 1,303 | 100.00 | 1,303 |
| PLAT VIII. UNSPRAYED. | | | | | | | | | |
| First and second broods: | | | | | | | | | |
| Calyx | 1,324 | 686 | 970 | 1,142 | 1,472 | 999 | 6,593 | 55.96 | .......... |
| Side | 492 | 1,506 | 333 | 437 | 725 | 416 | 3,909 | 33.18 | .......... |
| Stem | 248 | 235 | 206 | 182 | 268 | 140 | 1,279 | 10.86 | .......... |
| Total | 2,064 | 2,427 | 1,509 | 1,761 | 2,465 | 1,555 | 11,781 | 100.00 | 11,781 |

On the demonstration plat there was a total of 147 larvæ; on the one-spray plat, 1,303 larvæ; and on the unsprayed plat, 11,781 larvæ. The notably greater number on the one-spray plat than on the demonstration plat is probably due to the former being next to the unsprayed plat, as above mentioned, from which moths no doubt migrated during the season.

A more ready comparison of the efficiency of the treatments of Plats II, VII, and VIII is given in Table XIII.

TABLE XIII.—*Efficiency of the demonstration and one-spray treatments for the codling moth as shown by the percentage of wormy apples. Camden, Del., 1911.*

| Plat No. | Percentage of wormy apples. | | | | Total number of wormy apples. | Total number of apples. |
|---|---|---|---|---|---|---|
| | Calyx. | Side. | Stem. | Total. | | |
| II. Demonstration | 0.03 | 0.62 | 0.08 | 0.73 | 147 | 20,068 |
| VII. One-spray | .36 | 5.96 | .84 | 7.16 | 1,303 | 18,184 |
| VIII. Unsprayed | 31.67 | 18.78 | 6.15 | 56.60 | 11,781 | 20,814 |

It will be seen here that the one-spray method was nearly as effective as the demonstration in preventing calyx entrance, the difference in favor of the demonstration treatment being 0.33 per cent. The one-spray method in this case shows considerable protection against side worminess, but not so much as the demonstration, which shows an increase in side-entrance protection over the one-spray method of 5.34 per cent. The unsprayed plat shows 56.60 per cent of wormy fruit, so there is a total saving of 55.87 per cent of the crop by the demonstration treatment and 49.44 per cent by the one-spray treatment.

### THE PLUM CURCULIO.

The plum curculio was considerably in evidence in the Bancroft orchard during 1911. The unsprayed plat (Table XIV) shows only 65.13 per cent free from curculio injury, while the demonstration plat shows 90.37 per cent free from this insect as against 85.69 per cent on the one-spray plat, the demonstration plat showing an increase in sound fruit over the one-spray plat of 4.68. The difference in favor of the demonstration plat was very probably influenced by the location of the one-spray plat as previously mentioned under the discussion of codling-moth injury.

Table XIV.—*Injury by the plum curculio for entire season. Plats II, VII, and VIII. Camden, Del., 1911.*

PLAT II. LIME-SULPHUR DEMONSTRATION.

| Number of punctured and sound apples, etc., per tree. | | | | | | | Total for plat. | Total per cent of fruit free from injury. |
|---|---|---|---|---|---|---|---|---|
| | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | | |
| Number of punctures | 641 | 265 | 440 | 281 | 821 | 374 | 2,822 | .......... |
| Number of fruit punctured | 384 | 169 | 337 | 204 | 576 | 261 | 1,931 | .......... |
| Number of sound fruit | 3,298 | 2,238 | 3,435 | 2,500 | 4,201 | 2,465 | 18,137 | .......... |
| Number of fruit | 3,682 | 2,407 | 3,772 | 2,704 | 4,777 | 2,726 | 20,068 | .......... |
| Per cent free from injury | 89.57 | 92.97 | 91.06 | 92.45 | 87.94 | 90.42 | .......... | 90.37 |

PLAT VII. ONE-SPRAY METHOD.

| | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Total for plat. | Total per cent of fruit free from injury. |
|---|---|---|---|---|---|---|---|---|
| Number of punctures | 710 | 349 | 614 | 784 | 548 | 779 | 3,784 | .......... |
| Number of fruit punctured | 458 | 252 | 417 | 606 | 444 | 425 | 2,602 | .......... |
| Number of sound fruit | 2,106 | 1,842 | 2,400 | 3,918 | 2,649 | 2,667 | 15,582 | .......... |
| Number of fruit | 2,564 | 2,094 | 2,817 | 4,524 | 3,093 | 3,092 | 18,184 | .......... |
| Per cent free from injury | 82.13 | 87.96 | 85.19 | 86.60 | 85.64 | 86.25 | .......... | 85.69 |

PLAT VIII. UNSPRAYED.

| | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Total for plat. | Total per cent of fruit free from injury. |
|---|---|---|---|---|---|---|---|---|
| Number of punctures | 1,322 | 2,602 | 1,700 | 1,599 | 2,964 | 1,898 | 12,085 | .......... |
| Number of fruit punctured | 902 | 1,599 | 1,114 | 889 | 1,712 | 1,041 | 7,257 | .......... |
| Number of sound fruit | 2,566 | 3,299 | 2,107 | 1,834 | 2,431 | 1,320 | 13,557 | .......... |
| Number of fruit | 3,468 | 4,898 | 3,221 | 2,723 | 4,143 | 2,361 | 20,814 | .......... |
| Per cent free from injury | 73.99 | 67.35 | 65.41 | 67.34 | 58.67 | 55.90 | .......... | 65.13 |

## EXPERIMENTS IN KANSAS.

The experiments in Kansas during the season of 1911 were carried out in the Thomas Fruit Farm orchard near Wichita, Kans. This is a large orchard consisting of 76 acres, and is quite level. The soil is a sandy-loam type and was not well cultivated during the season.

The trees were 20 years old and well pruned. The orchard consists of blocks of several varieties, but the experimental plats were laid out in a block of Winesaps. The plats begin at the south-central side of the orchard and extend north about halfway across. The unsprayed plat was located between Plats I and II, as is shown in the accompanying diagram (fig. 26). The trees surrounding the plats were

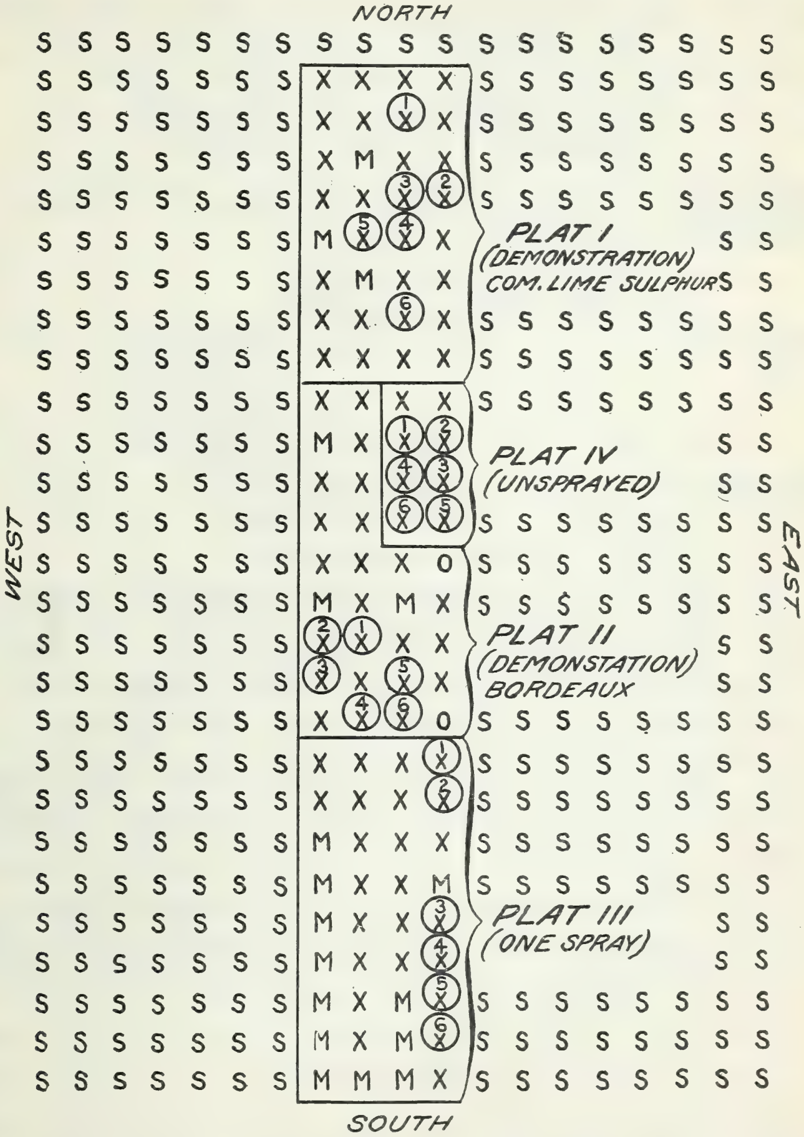
NORTH
PLAT I
(DEMONSTRATION)
COM. LIME SULPHUR
PLAT IV
(UNSPRAYED)
PLAT II
(DEMONSTATION)
BORDEAUX
PLAT III
(ONE SPRAY)
WEST
EAST
SOUTH

FIG. 26.—Diagram showing arrangement of plats and trees in the Thomas Fruit Farm orchard, near Wichita, Kans. Trees counted are indicated by circles, the numbers agreeing with the numbers in the tables. Trees marked *X*, Winesap variety. Those marked *S*, mixed varieties sprayed by owner. (Original.)

sprayed by the owner. Plat I includes 32 trees; Plat II, 24 trees; Plat III, 36 trees; and Plat IV, 8 trees. The treatments which the respective plats received are shown in Table XV.

TABLE XV.—*Treatments and dates of applications for the codling moth and the plum curculio. One-spray method. Wichita, Kans., 1911.*

| Dates of application. | Plat I (demonstration). Commercial lime-sulphur and arsenate of lead. | Plat II (demonstration). Bordeaux and arsenate of lead. | Plat III (one-spray method). Commercial lime-sulphur and arsenate of lead. | Plat IV. |
|---|---|---|---|---|
| First application, Apr. 14 (before blossoms opened). | Not drenched. Blizzard nozzles. Coarse spray. Arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½-50). Pressure, 200 pounds. | Not drenched. Blizzard nozzles. Coarse spray. Arsenate of lead, 2 pounds to 50 gallons. Bordeaux (3-4-50). Pressure, 200 pounds. | Unsprayed. | Unsprayed. |
| Second application, May 1 (after petals dropped). | do | do | Drenched with arsenate of lead, 2 pounds to 50 gallons commercial lime-sulphur (1½-50). Blizzard nozzles. Coarse spray. Pressure, 200-240 pounds. | Do. |
| Third application, May 19-22. | do | do | Unsprayed. | Do. |
| Fourth application, July 1. | do | do | do | Do. |

Plats I and II, the demonstration plats, received four applications in all, the first, before blooming but after the cluster buds opened, being applied for the cankerworm and apple scab. Plat I received arsenate of lead at the rate of 2 pounds to 50 gallons of commercial lime-sulphur. On Plat II Bordeaux was used instead of lime-sulphur; otherwise the treatments of the two plats were the same. Plat III, the one-spray plat, received only one application of arsenate of lead, 2 pounds to 50 gallons of commercial lime-sulphur. This was applied just after the petals fell. Plats I and II received 10 gallons of spray per tree each for the application at the time of the falling of the petals, while Plat III received 13 gallons per tree at that time. The coarse spray-nozzle was used on all plats for each application, but only the one-spray plat was drenched.

### THE CODLING MOTH.

Table XVI shows the results of treatments of Plats I, II, and III, compared with the unsprayed plat (Plat IV) as to injury from the codling moth.

TABLE XVI.—*Number of sound and wormy apples for each tree from lime-sulphur, Bordeaux, one-spray, and unsprayed plats. Wichita, Kans., 1911.*

| Condition of fruit. | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | Total for plat. | Total per cent of sound fruit. |
|---|---|---|---|---|---|---|---|---|
| PLAT I. LIME-SULPHUR DEMONSTRATION. | | | | | | | | |
| Wormy | 111 | 194 | 157 | 177 | 127 | 204 | 970 | |
| Sound | 2,993 | 3,214 | 3,409 | 3,079 | 2,867 | 4,013 | 19,575 | |
| Total | 3,104 | 3,408 | 3,566 | 3,256 | 2,994 | 4,217 | 20,545 | |
| Per cent sound | 96.42 | 94.30 | 95.59 | 94.56 | 95.75 | 95.16 | | 95.28 |
| PLAT II. BORDEAUX DEMONSTRATION. | | | | | | | | |
| Wormy | 579 | 457 | 651 | 460 | 474 | 594 | 3,215 | |
| Sound | 3,139 | 2,324 | 3,389 | 3,267 | 3,475 | 2,525 | 18,119 | |
| Total | 3,718 | 2,781 | 4,040 | 3,727 | 3,949 | 3,119 | 21,334 | |
| Per cent sound | 84.42 | 83.56 | 83.88 | 87.65 | 87.99 | 80.95 | | 84.93 |
| PLAT III. ONE-SPRAY METHOD. | | | | | | | | |
| Wormy | 285 | 397 | 193 | 213 | 287 | 168 | 1,543 | |
| Sound | 2,168 | 3,552 | 630 | 602 | 721 | 529 | 8,202 | |
| Total | 2,453 | 3,949 | 823 | 815 | 1,008 | 697 | 9,745 | |
| Per cent sound | 88.38 | 89.94 | 76.54 | 73.86 | 71.52 | 75.89 | | 84.16 |
| PLAT IV. UNSPRAYED. | | | | | | | | |
| Wormy | 1,769 | 1,890 | 2,232 | 2,709 | 2,072 | 2,245 | 12,917 | |
| Sound | 1,114 | 1,166 | 960 | 1,000 | 704 | 645 | 5,589 | |
| Total | 2,883 | 3,056 | 3,192 | 3,709 | 2,776 | 2,890 | 18,506 | |
| Per cent sound | 38.64 | 38.15 | 30.07 | 26.96 | 25.36 | 22.31 | | 30.20 |

By again comparing the one-spray method (Plat III) with the commercial lime-sulphur plat (Plat I), as has been done in the foregoing experiments, it will be noted that Plat I shows 95.28 per cent of fruit free from codling-moth injury as against 84.16 per cent free from this insect on Plat III. Plat IV, the unsprayed plat, shows only 30.20 per cent fruit free from codling-moth injury. Thus the commercial lime-sulphur demonstration plat shows an increase of sound fruit over the unsprayed plat of 65.08 per cent, while the one-spray plat shows an increase of 53.96 per cent over the unsprayed plat. The number of apples counted on the four plats, respectively, were 20,545, 21,334, 9,745, and 18,506, making a total of 70,130 for the four plats. One point in favor of the demonstration plat is that there were over twice as many apples on the count trees, which would tend to decrease the total percentage of wormy fruit. However, as will be noted later, there were 573 more codling-moth larvæ on the one-spray plat than on the lime-sulphur demonstration plat.

The Bordeaux demonstration plat (No. II) did not give as good results as the lime-sulphur demonstration plat, the percentage of fruit free from codling-moth injury being 84.93, practically the same as on the one-spray plat. The notable difference between the two demonstration plats in percentage of sound fruit may be due to its location relative to the unsprayed plat or to some other local condition.

Table XVII shows the places of entrance of fruit by total larvæ for each tree of each plat.

TABLE XVII.—*Places of entrance of fruit by total larvæ of the codling moth for each tree of each plat. Wichita, Kans, 1911.*

PLAT I. LIME-SULPHUR DEMONSTRATION.

| Total number of larvæ and place of entrance of fruit for each tree, first and second broods combined. | | | | | | | Total for plat. | Percentage of larvæ entering at calyx, side, and stem. | Total number of larvæ. |
|---|---|---|---|---|---|---|---|---|---|
| Place of entrance. | Tree 1. | Tree 2. | Tree 3. | Tree 4. | Tree 5. | Tree 6. | | | |
| First and second broods: | | | | | | | | | |
| Calyx | 19 | 13 | 7 | 11 | 6 | 9 | 65 | 6.70 | .......... |
| Side | 92 | 174 | 144 | 149 | 112 | 174 | 845 | 87.11 | .......... |
| Stem | 0 | 7 | 6 | 17 | 9 | 21 | 60 | 6.19 | .......... |
| Total | 111 | 194 | 157 | 177 | 127 | 204 | 970 | 100.00 | 970 |
| PLAT II. BORDEAUX DEMONSTRATION. | | | | | | | | | |
| First and second broods: | | | | | | | | | |
| Calyx | 28 | 19 | 27 | 17 | 35 | 26 | 152 | 4.73 | .......... |
| Side | 496 | 354 | 535 | 394 | 373 | 502 | 2,654 | 82.55 | .......... |
| Stem | 55 | 84 | 89 | 49 | 66 | 66 | 409 | 12.72 | .......... |
| Total | 579 | 457 | 651 | 460 | 474 | 594 | 3,215 | 100.00 | 3,215 |
| PLAT III. ONE-SPRAY METHOD. | | | | | | | | | |
| First and second broods: | | | | | | | | | |
| Calyx | 23 | 32 | 14 | 18 | 24 | 20 | 131 | 8.49 | .......... |
| Side | 236 | 323 | 151 | 172 | 239 | 134 | 1,255 | 81.34 | .......... |
| Stem | 26 | 42 | 28 | 23 | 24 | 14 | 157 | 10.17 | .......... |
| Total | 285 | 397 | 193 | 213 | 287 | 168 | 1,543 | 100.00 | 1,543 |
| PLAT IV. UNSPRAYED. | | | | | | | | | |
| First and second broods: | | | | | | | | | |
| Calyx | 1,039 | 1,107 | 1,338 | 1,629 | 1,280 | 1,400 | 7,793 | 60.33 | .......... |
| Side | 415 | 493 | 557 | 662 | 499 | 530 | 3,156 | 24.43 | .......... |
| Stem | 315 | 290 | 337 | 418 | 293 | 315 | 1,968 | 15.24 | .......... |
| Total | 1,769 | 1,890 | 2,232 | 2,709 | 2,072 | 2,245 | 12,917 | 100.00 | 12,917 |

In this experiment a slightly smaller percentage of larvæ entered at the calyx end of the apple on the lime-sulphur demonstration plat than on the one-spray plat, the percentages being 6.70 and 8.49, respectively. As will be noted under the above discussion of worminess of the apples, a coarse-spray nozzle and a high pressure were used for all applications on all the sprayed plats. Such treatment would therefore be expected to result in a lower percentage of larvæ entering at the calyx end on the demonstration plat than if a mist spray had been used, as was done in the foregoing experiments. The total number of larvæ on Plats I, II, III, and IV are, respectively, 970, 3,215, 1,543, and 12,917.

In protecting the calyx end of the apple there is shown a difference between the two treatments of 1.02 per cent in favor of the demonstration, which is a greater difference than occurred in any of the other experiments. This result is probably largely due to the use of coarse-spray nozzles on all sprayed plats as mentioned above. The demonstration treatment saved a total of 95.28 per cent of the crop, which was 11.11 per cent more than that saved by the one-spray treatment. The efficiency of the one-spray and demonstration treatments in preventing worminess is shown in condensed form in Table XVIII.

TABLE XVIII.—*Efficiency of the demonstration and one-spray treatments against the codling moth as shown by the percentage of wormy apples. Wichita, Kans., 1911.*

| Plat No. | Percentage of wormy apples. | | | | Total number of wormy apples. | Total number of apples. |
|---|---|---|---|---|---|---|
| | Calyx. | Side. | Stem. | Total. | | |
| I. Demonstration | 0.32 | 4.11 | 0.29 | 4.72 | 970 | 20,545 |
| III. One-spray | 1.34 | 12.88 | 1.61 | 15.83 | 1,543 | 9,745 |
| IV. Unsprayed | 42.10 | 17.05 | 10.64 | 69.79 | 12,917 | 18,506 |

## SUMMARY OF RESULTS.

The percentages of fruit free from codling moth and plum curculio injury on the demonstration, one-spray, and unsprayed plats from the several localities are given for comparison in Table XIX. The average percentage of fruit free from codling-moth injury for the four orchards gives for the demonstration treatment 96.72 per cent as against 90.76 per cent for the one-spray method, a gain of 5.96 per cent in favor of the demonstration. The average percentage of fruit free from this insect on the unsprayed plats was 52.70, making a gain in favor of the demonstration plats over the unsprayed plats of 44.02 per cent.

TABLE XIX.—*Percentages of fruit free from injury by the codling moth and plum curculio on one-spray, demonstration, and unsprayed plats in Virginia, Michigan, Delaware, and Kansas, in 1910 and 1911.*

| Locality. | Codling moth. | | | Plum curculio. | | |
|---|---|---|---|---|---|---|
| | Demonstration. | One-spray. | Unsprayed. | Demonstration. | One-spray. | Unsprayed. |
| Fishersville, Va | 99.42 | 99.01 | 84.49 | 94.72 | 94.37 | 90.38 |
| Fennville, Mich | 92.91 | 87.05 | 52.73 | .......... | .......... | .......... |
| Camden, Del | 99.27 | 92.83 | 43.40 | 90.37 | 85.69 | 65.13 |
| Wichita, Kans | 95.28 | 84.16 | 30.20 | .......... | .......... | .......... |
| Average of four localities | 96.72 | 90.76 | 52.70 | 92.54 | 90.03 | 77.75 |

In Table XX is given a summary of the results of the one-spray experiments carried out by this bureau in 1909 (Bul. 80, Part VII, Revised) for the purpose of comparison with the foregoing results of the 1910 and 1911 experiments (Table XIX).

TABLE XX.—*Percentages of fruit free from injury by the codling moth and plum curculio on demonstration, one-spray, and unsprayed plats in Arkansas, Virginia, and Michigan in 1909.*

| Locality. | Codling moth. | | | Plum curculio. | | |
|---|---|---|---|---|---|---|
| | Demonstration. | One-spray. | Unsprayed. | Demonstration. | One-spray. | Unsprayed. |
| Siloam Springs, Ark | 98.12 | 92.76 | 66.74 | 82.88 | 86.34 | 8.85 |
| Crozet, Va | 94.13 | 84.07 | 53.02 | 86.89 | 73.93 | 54.02 |
| Mount Jackson, Va | 92.74 | 91.68 | 54.00 | 40.82 | 57.90 | 27.23 |
| Saugatuck, Mich | 97.66 | 93.61 | 77.79 | 98.77 | 97.54 | 87.42 |
| Average of four localities | 96.57 | 91.46 | 65.14 | 83.37 | 77.10 | 49.17 |

In comparing Tables XIX and XX it will be seen that for the two sets of experiments the average percentages of fruit free from codling-moth injury on the sprayed plats were practically the same, while on the unsprayed plats the fruit was considerably less infested with this insect in 1909 than in 1910 and 1911. The average percentage of fruit free from this insect for the demonstration treatment in 1909 was 96.57 per cent as against 96.72 per cent in 1910 and 1911, a difference of only 0.15 per cent. In the case of the one-spray treatment there was a difference of only 0.70 per cent in the average percentages of fruit free from codling-moth injury.

Table XXI shows the total efficiency and the protection afforded to each of the different parts of the apple by the treatments for the four orchards. It will be seen from the average of the four localities that nearly 60 per cent of the total larvæ on the unsprayed plats entered through the calyx, while on the sprayed plats 83 per cent of the worms entered the fruit by way of the side, showing that the poison in the calyx is much more efficient than that on the side of the fruit.

The averages of the percentages of apples wormy at the calyx on the demonstration and the one-spray treatments are practically the same, there being a difference of only 0.3 per cent in favor of the demonstration treatment. The one-spray treatment was about one-third less effective in preventing side entrance than the demonstration treatment. Both methods were effective in reducing entrance at the stem end, the demonstration slightly more so than the one-spray.

TABLE XXI.—*Efficiency of the demonstration and one-spray treatments against the codling moth as shown by the percentages of wormy apples, Virginia, 1910, Michigan, Delaware, and Kansas, 1911.*

| Locality. | Percentage of wormy apples. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Calyx. | | | Side. | | | Stem. | | | Total. | | |
| | Demonstration. | One-spray. | Unsprayed. | Demonstration. | One-spray. | Unsprayed. | Demonstration. | One-spray. | Unsprayed. | Demonstration. | One-spray. | Unsprayed. |
| Fishersville, Va | 0.19 | 0.13 | 9.89 | 0.26 | 0.54 | 2.53 | 0.12 | 0.31 | 3.07 | 0.57 | 0.98 | 15.49 |
| Fennville, Mich.[1] | .96 | .86 | 25.62 | 5.98 | 11.64 | 17.95 | .14 | .44 | 3.69 | 7.08 | 12.94 | 47.26 |
| Camden, Del | .03 | .36 | 31.67 | .62 | 5.96 | 18.78 | .08 | .84 | 6.15 | .73 | 7.16 | 56.60 |
| Wichita, Kans | .32 | 1.34 | 42.10 | 4.11 | 12.88 | 17.05 | .29 | 1.61 | 10.64 | 4.72 | 15.83 | 69.79 |
| Average | .37 | .67 | 27.32 | 2.74 | 7.75 | 14.08 | .16 | .80 | 5.89 | 3.27 | 9.23 | 47.28 |

[1] The figures under calyx, side, and stem for Fennville are based on the number of entrance holes instead of the number of apples entered.

For the purpose of comparing the results of the experiments conducted in 1910 and 1911 with those conducted in 1909, as to the efficiency of the two methods of treatment as shown by the percentages of wormy apples, Table XXII is presented. This table shows that the results in the two sets of experiments were practically the same as to protection of the calyx and stem ends of the apple from codling-moth infestation. The one-spray method was less effective in preventing side entrance in 1910–11 than in 1909.

TABLE XXII.—*Efficiency of the demonstration and one-spray treatments against the codling moth as shown by the percentages of wormy apples. Results of experiments in 1909 compared with those in 1910–11.*

| Years. | Percentage of wormy apples. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Calyx. | | | Side. | | | Stem. | | | Total. | | |
| | Demonstration. | One-spray. | Unsprayed. | Demonstration. | One-spray. | Unsprayed. | Demonstration. | One-spray. | Unsprayed. | Demonstration. | One-spray. | Unsprayed. |
| 1909 | 0.57 | 0.68 | 23.85 | 2.87 | 7.64 | 8.92 | 0.18 | 0.59 | 2.21 | 3.42 | 8.55 | 34.86 |
| 1910–11 | .37 | .67 | 27.32 | 2.74 | 7.75 | 14.08 | .16 | .80 | 5.89 | 3.27 | 9.23 | 47.28 |

## CONCLUSIONS.

The results of experiments reported in the present paper corroborate those earlier obtained by the bureau (Bul. 80, Pt. VII, p. 146) as to the efficiency of the one-spray method in controlling the codling moth and plum curculio. Bringing together the results of all of the tests which represent several seasons and varied conditions, it is found that the average of the percentages of sound fruit from a single spraying is 90.64 as compared with 96.19, the average of the percentages of sound fruit on the demonstration plats receiving from three to five applications. The unsprayed plats show an average of 57.79 per cent of fruit free from codling-moth injury. The variation in percentage of sound fruit is considerably greater with plats receiving the single application than where the demonstration treatment was given, indicating, perhaps, a less degree of insurance from injury, especially under unusual seasonal conditions, as in case of injury of fruit by hail, etc., as occurred in Virginia during 1909. For the entire period the range in percentage of sound fruit on the demonstration plat is from 92.91 (Michigan, 1911) to 99.42 (Virginia, 1910) and on the one-spray the range is from 84.07 per cent (Virginia, 1909) to 99.01 per cent (Virginia, 1910).

In Prof. Gossard's work in Ohio (Bul. 191, Ohio Agr. Exp. Sta.) a single spraying resulted in 91.60 per cent of sound fruit as compared with 45.80 per cent from unsprayed trees. In West Virginia, Rumsey (Bul. 127, W. Va. Univ. Agr. Exp. Sta.) obtained by the one-spray method 97.40 per cent of fruit free from codling moth, as compared with 96.7 per cent sound fruit from four applications. In these tests the unsprayed trees showed 65.9 per cent only of sound fruit.

Dr. Felt's very valuable data obtained in New York State (Journ. Econ. Ent., Vol. V, p. 153, 1912), and covering three years of experimental work, shows for the entire period for plats receiving a single application 97.35 per cent of sound fruit; for plats receiving three applications 99.22 per cent of fruit free from worms as compared with 79.05 per cent of sound fruit on unsprayed trees.

The above data, while obtained under rather variable conditions of experiment, establish beyond doubt that a single thorough application of an arsenate-of-lead spray at once after the falling of the petals will protect from codling-moth injury a large percentage of the crop, though not quite so high a percentage as by several applications designed to protect the fruit during the entire season.

While the information as regards the plum curculio is not so full as desirable, it also appears that this insect is controlled by the single thorough treatment practically as well as by the usual three or four applications. Thus the six orchards where data were obtained by the bureau on the curculio give an average percentage (average of percentages) of fruit free from injury on the one-spray plat of 82.62 as compared with 82.40 per cent of sound fruit on plats receiving the demonstration treatment. The percentage of sound fruit on the unsprayed trees was 55.50. Results obtained by Rumsey (l. c.) fully substantiate the foregoing. In his work a single spraying gave 87.5 per cent of crop free from injury as compared with 86.1 per cent of sound fruit on the plat receiving four applications, the check plat showing 67.9 per cent of uninjured fruit. In the case of the curculio the degree of protection afforded by spraying varies much more widely than for the codling moth, depending upon the abundance of the insects and the quantity of fruit present on the trees, as may be seen by reference to the tables on the subject in the foregoing pages and in the previous report (Bul. 80, Pt. VII).

It would therefore appear from the foregoing that for the control of the codling moth and plum curculio under eastern conditions, a single thorough spraying is about as efficient as a schedule of treatment requiring three or more applications; were these the only troubles to be considered, the orchardist would hardly be justified in making additional applications.

The reader should bear in mind, however, that in the experimental work reported applications have been made with an unusual degree of thoroughness. It will be evident that the value of a single spraying depends entirely on the extent to which the calyx cups of the fruit are filled with the poison. Perfect spraying in this regard should prevent all calyx entrance of fruit by the larvæ. As a matter of fact, in our plats sprayed most thoroughly we have not been able entirely to prevent calyx entrances, though such a degree of thoroughness has been obtained, as reported by other experimenters in the Western States. The point can not be too strongly emphasized that thoroughness is the keynote in obtaining satisfactory results from the one-spray method.

The necessity of filling the inner calyx cup with poison, as insisted upon by western entomologists, and the employment of a nozzle throwing a coarse spray, as the Bordeaux, has not been, on the whole, confirmed under eastern conditions.

It appears that as good results follow the use of nozzles throwing a fine spray as where coarse nozzles are used. It is also clear that under our conditions there is no necessity to fill the inner calyx cup to control the codling moth successfully, and indeed this is prevented by the stamen bars which remain turgid and shield the cavity below, even after the calyx lobes are nearly closed. There can be no question of the desirability of high pressure in spraying (175 to 250 pounds), and most orchardists appreciate this fact. The practical utility of the one-spray method under eastern conditions is greatly lessened on account of the necessity in most regions of giving orchards additional applications of fungicides for the prevention of such diseases as apple scab, bitter rot, apple blotch, sooty blotch, etc. In regions where bitter rot and apple blotch are not troublesome and in the case of varieties little susceptible to apple scab, the single application would be most likely to have value, and orchardists thus situated should determine the applicability of the method under their respective conditions. Where additional sprayings are necessary for fungous diseases, an arsenical should be added, as the additional cost is slight.

One very important fact has been developed as a result of these studies, namely, the importance of great thoroughness in spraying after the falling of the petals. While this has been insisted on by entomologists for many years, yet the great extent to which the codling moth may be controlled by this one treatment has not been appreciated. The aim should be to poison the calyx cup of each and every apple on the tree, irrespective of whether subsequent treatments are to be given. Imperfect spraying at this time can not be remedied by any number of later applications.

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# PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

## LIFE HISTORY OF THE CODLING MOTH IN THE SANTA CLARA VALLEY OF CALIFORNIA.

By P. R. Jones and W. M. Davidson,
*Engaged in Deciduous Fruit Insect Investigations.*

### INTRODUCTION.

The codling moth in California presents so many differences in life history in comparison with that which has been learned in the East, as well as so many local conditions associated with each particular valley in this State, that there has been felt the need of a more comprehensive study of its life history with the temperature conditions influencing the same.

The data presented in this paper have been collected during the past three years, 1909, 1910, and 1911, only partial records being obtained for the first year but fairly complete notes for the latter two.

The Santa Clara Valley is practically one large deciduous-fruit orchard from 60,000 to 70,000 acres in extent, lying between the Santa Cruz Range of mountains on the west and the Mount Hamilton Range on the east and extending from the San Francisco Bay just north of Alviso 50 to 60 miles south past the town of Gilroy. The valley varies in width from 5 to 20 miles.

According to the United States Weather Bureau the average mean temperature for the whole year in this region is 58.1° F., compiled from a record of 36 years. The annual mean precipitation for this time has been 14.79 inches, with practically all of the rainfall in January, February, March, November, and December. It will thus be seen that the codling moth is influenced by a low dry mean temperature with little or no rainfall during the period it is attacking the fruit.

The data for 1909 were gathered by Messrs. Dudley Moulton, formerly of this bureau, and J. R. Horton of this bureau; that of 1910 and 1911 by Mr. F. L. Young, formerly of this bureau, and by both of the authors. Miss Emma Weber has contributed many life-history observations also during the years 1910 and 1911.

An attempt has been made to follow the plan of presentation as given by Messrs. Jenne and Hammar in their respective studies on the codling moth.[1]

## SEASONAL-HISTORY STUDIES OF 1909.

### SPRING BROOD OF PUPÆ.

The record for this brood was made from larvæ collected January 2 in the field from under the bark on apple trees and placed in separate vials for an individual pupation record. Table I records the time of pupation, time of emergence, and length of pupal period.

TABLE I.—*Spring brood of pupæ. Length of the pupal stage for wintering larvæ collected in January, 1909, from banded trees.*

| No. of individual. | Date of— | | Length of pupal stage. | No. of individual. | Date of— | | Length of pupal stage. |
|---|---|---|---|---|---|---|---|
| | Pupation. | Emergence. | | | Pupation. | Emergence. | |
| | | | *Days.* | | | | *Days.* |
| 1 | Feb. 20 | Apr. 17 | 56 | 17 | Mar. 26 | May 3 | 38 |
| 2 | Mar. 4 | ...do..... | 48 | 18 | Mar. 27 | ...do..... | 37 |
| 3 | ...do..... | ...do..... | 53 | 19 | Mar. 29 | Apr. 28 | 30 |
| 4 | Mar. 5 | ...do..... | 52 | 20 | ...do..... | May 3 | 35 |
| 5 | Mar. 8 | Apr. 28 | 51 | 21 | ...do..... | ...do..... | 35 |
| 6 | Mar. 9 | Apr. 26 | 48 | 22 | Mar. 30 | May 6 | 37 |
| 7 | ...do..... | ...do..... | 48 | 23 | Apr. 1 | May 1 | 30 |
| 8 | ...do..... | Apr. 28 | 50 | 24 | ...do..... | May 3 | 32 |
| 9 | Mar. 11 | ...do..... | 48 | 25 | ...do..... | ...do..... | 32 |
| 10 | Mar. 12 | Apr. 29 | 48 | 26 | ...do..... | ...do..... | 32 |
| 11 | Mar. 13 | May 1 | 49 | 27 | ...do..... | ...do..... | 32 |
| 12 | Mar. 15 | May 3 | 49 | 28 | Apr. 6 | May 10 | 34 |
| 13 | Mar. 23 | ...do..... | 41 | 29 | Apr. 9 | May 11 | 32 |
| 14 | Mar. 24 | Apr. 28 | 35 | 30 | Apr. 12 | May 4 | 22 |
| 15 | ...do..... | ...do..... | 35 | 31 | ...do..... | May 17 | 35 |
| 16 | ...do..... | May 1 | 38 | | | | |

Thus the pupal stage varied from 22 to 56 days, with an average of 40.22 days. The first pupation occurred February 20 and the last April 12, while the first adult emerged April 17 and the last May 17. The pupal period, therefore, occupied the time between February 20 and May 17, or 87 days. No record was kept with regard to the sexes of either larvæ or adults. Table II shows the variations in the length of the pupal stage and is a summary of Table I.

TABLE II.—*Spring brood of pupæ. Variations in the length of the pupal stage as recorded in Table I.*

| Number of pupæ. | Days. | Number of pupæ. | Days. | Number of pupæ. | Days. | Number of pupæ. | Days. |
|---|---|---|---|---|---|---|---|
| 1 | 22 | 5 | 35 | 4 | 48 | 1 | 52 |
| 2 | 30 | 2 | 37 | 2 | 49 | 2 | 53 |
| 5 | 32 | 2 | 38 | 1 | 50 | 1 | 56 |
| 1 | 34 | 1 | 41 | 1 | 51 | | |

This record is for only 31 pupæ and is somewhat irregular.

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[1] Bull. 80, Pts. I and VI, and Bul. 115, Pt. I, Bur. Ent., U. S. Dept. Agr.

### SPRING BROOD OF MOTHS.

No record was taken of the adult emergence of the overwintering brood in 1909 other than that recorded in Table I for the pupal stage.

## FIRST GENERATION.

### FIRST BROOD OF EGGS.

No record in 1909.

### FIRST BROOD OF LARVÆ.

No record in 1909.

### FIRST BROOD OF PUPÆ.

Larvæ were collected at intervals in June, July, and August from banded trees and placed in vials for pupation in lots of varying numbers. Table III shows the pupal period for 182 individuals. In all 207 larvæ pupated, but 25, or 12.08 per cent, perished before the adults issued.

TABLE III.—*Pupæ of the first brood. Length of the pupal stage from material collected in 1909 on banded trees.*

| Number of individual. | Date of— | | Length of pupal stage. |
|---|---|---|---|
| | Pupation. | Emergence. | |
| | | | *Days.* |
| 1 | June 25 | July 13 | 18 |
| 2 | ...do.... | ...do.... | 18 |
| 3 | ...do.... | ...do.... | 18 |
| 4 | ...do.... | ...do.... | 18 |
| 5 | ...do.... | ...do.... | 18 |
| 6 | ...do.... | ...do.... | 18 |
| 7 | ...do.... | ...do.... | 18 |
| 8 | ...do.... | ...do.... | 18 |
| 9 | ...do.... | ...do.... | 18 |
| 10 | ...do.... | ...do.... | 18 |
| 11 | ...do.... | ...do.... | 18 |
| 12 | ...do.... | ...do.... | 18 |
| 13 | ...do.... | ...do.... | 18 |
| 14 | ...do.... | July 14 | 19 |
| 15 | ...do.... | July 15 | 20 |
| 16 | ...do.... | ...do.... | 20 |
| 17 | ...do.... | ...do.... | 20 |
| 18 | ...do.... | ...do.... | 20 |
| 19 | ...do.... | July 16 | 21 |
| 20 | ...do.... | ...do.... | 21 |
| 21 | ...do.... | ...do.... | 21 |
| 22 | ...do.... | July 19 | 24 |
| 23 | ...do.... | July 26 | 31 |
| 24 | June 26 | July 14 | 18 |
| 25 | ...do.... | ...do.... | 18 |
| 26 | ...do.... | ...do.... | 18 |
| 27 | ...do.... | ...do.... | 18 |
| 28 | ...do.... | ...do.... | 18 |
| 29 | ...do.... | ...do.... | 18 |
| 30 | ...do.... | ...do.... | 18 |
| 31 | ...do.... | July 15 | 19 |
| 32 | ...do.... | ...do.... | 19 |
| 33 | ...do.... | July 16 | 20 |
| 34 | ...do.... | ...do.... | 20 |
| 35 | ...do.... | ...do.... | 20 |
| 36 | ...do.... | ...do.... | 20 |
| 37 | ...do.... | ...do.... | 20 |
| 38 | June 26 | July 16 | 20 |
| 39 | ...do.... | ...do.... | 20 |
| 40 | ...do.... | ...do.... | 20 |
| 41 | ...do.... | ...do.... | 20 |
| 42 | ...do.... | ...do.... | 20 |
| 43 | ...do.... | ...do.... | 20 |
| 44 | ...do.... | ...do.... | 20 |
| 45 | ...do.... | ...do.... | 20 |
| 46 | ...do.... | ...do.... | 20 |
| 47 | ...do.... | ...do.... | 20 |
| 48 | ...do.... | ...do.... | 20 |
| 49 | ...do.... | July 17 | 21 |
| 50 | ...do.... | ...do.... | 21 |
| 51 | ...do.... | ...do.... | 21 |
| 52 | ...do.... | ...do.... | 21 |
| 53 | ...do.... | ...do.... | 21 |
| 54 | ...do.... | July 19 | 23 |
| 55 | ...do.... | July 20 | 24 |
| 56 | June 28 | July 16 | 18 |
| 57 | ...do.... | ...do.... | 18 |
| 58 | ...do.... | ...do.... | 18 |
| 59 | ...do.... | ...do.... | 18 |
| 60 | ...do.... | ...do.... | 18 |
| 61 | ...do.... | ...do.... | 18 |
| 62 | ...do.... | July 17 | 19 |
| 63 | ...do.... | ...do.... | 19 |
| 64 | ...do.... | ...do.... | 19 |
| 65 | ...do.... | ...do.... | 19 |
| 66 | ...do.... | ...do.... | 19 |
| 67 | ...do.... | ...do.... | 19 |
| 68 | ...do.... | ...do.... | 19 |
| 69 | ...do.... | ...do.... | 19 |
| 70 | ...do.... | ...do.... | 19 |
| 71 | ...do.... | ...do.... | 19 |
| 72 | ...do.... | ...do.... | 19 |
| 73 | ...do.... | ...do.... | 19 |
| 74 | ...do.... | ...do.... | 19 |

TABLE III.—*Pupæ of the first brood. Length of the pupal stage from material collected in 1909 on banded trees*—Continued.

| Number of individual. | Date of— | | Length of pupal stage. | Number of individual. | Date of— | | Length of pupal stage. |
|---|---|---|---|---|---|---|---|
| | Pupation. | Emergence. | | | Pupation. | Emergence. | |
| | | | *Days.* | | | | *Days.* |
| 75 | June 28 | July 17 | 19 | 129 | July 6 | July 26 | 20 |
| 76 | ...do..... | ...do..... | 19 | 130 | ...do..... | July 27 | 21 |
| 77 | ...do..... | ...do..... | 19 | 131 | ...do..... | July 28 | 22 |
| 78 | ...do..... | ...do..... | 19 | 132 | ...do..... | ...do..... | 22 |
| 79 | ...do..... | ...do..... | 19 | 133 | July 9 | July 31 | 22 |
| 80 | ...do..... | ...do..... | 19 | 134 | July 10 | July 29 | 19 |
| 81 | ...do..... | ...do..... | 19 | 135 | July 13 | July 28 | 15 |
| 82 | ...do..... | ...do..... | 19 | 136 | ...do..... | July 31 | 18 |
| 83 | ...do..... | July 19 | 21 | 137 | ...do..... | ...do..... | 18 |
| 84 | ...do..... | ...do..... | 21 | 138 | ...do..... | Aug. 4 | 22 |
| 85 | ...do..... | ...do..... | 21 | 139 | ...do..... | Aug. 5 | 23 |
| 86 | ...do..... | ...do..... | 21 | 140 | July 14 | ...do..... | 22 |
| 87 | ...do..... | ...do..... | 21 | 141 | July 22 | Aug. 14 | 23 |
| 88 | ...do..... | ...do..... | 21 | 142 | July 26 | Aug. 17 | 22 |
| 89 | ...do..... | ...do..... | 21 | 143 | July 29 | Aug. 21 | 23 |
| 90 | ...do..... | ...do..... | 21 | 144 | July 13 | July 31 | 18 |
| 91 | ...do..... | ...do..... | 21 | 145 | ...do..... | Aug. 3 | 21 |
| 92 | ...do..... | ...do..... | 21 | 146 | July 14 | ...do..... | 20 |
| 93 | ...do..... | ...do..... | 21 | 147 | ...do..... | Aug. 4 | 21 |
| 94 | ...do..... | ...do..... | 21 | 148 | July 15 | Aug. 3 | 19 |
| 95 | ...do..... | ...do..... | 21 | 149 | ...do..... | Aug. 4 | 20 |
| 96 | ...do..... | ...do..... | 21 | 150 | ...do..... | ...do..... | 20 |
| 97 | ...do..... | July 21 | 23 | 151 | July 16 | Aug. 3 | 18 |
| 98 | ...do..... | July 22 | 24 | 152 | ...do..... | Aug. 4 | 19 |
| 99 | ...do..... | ...do..... | 24 | 153 | ...do..... | Aug. 5 | 20 |
| 100 | June 29 | July 16 | 17 | 154 | ...do..... | ...do..... | 20 |
| 101 | ...do..... | ...do..... | 17 | 155 | ...do..... | Aug. 6 | 21 |
| 102 | ...do..... | July 17 | 18 | 156 | July 17 | Aug. 5 | 19 |
| 103 | ...do..... | July 19 | 20 | 157 | ...do..... | Aug. 7 | 21 |
| 104 | ...do..... | ...do..... | 20 | 158 | July 19 | Aug. 5 | 17 |
| 105 | ...do..... | ...do..... | 20 | 159 | ...do..... | Aug. 6 | 18 |
| 106 | ...do..... | ...do..... | 20 | 160 | ...do..... | ...do..... | 18 |
| 107 | ...do..... | ...do..... | 20 | 161 | ...do..... | Aug. 9 | 21 |
| 108 | ...do..... | July 20 | 21 | 162 | July 22 | ...do..... | 18 |
| 109 | ...do..... | ...do..... | 21 | 163 | ...do..... | Aug. 12 | 21 |
| 110 | ...do..... | July 21 | 22 | 164 | ...do..... | Aug. 13 | 22 |
| 111 | ...do..... | ...do..... | 22 | 165 | ...do..... | ...do..... | 22 |
| 112 | ...do..... | July 28 | 29 | 166 | ...do..... | Aug. 16 | 25 |
| 113 | June 30 | July 19 | 19 | 167 | July 24 | Aug. 18 | 25 |
| 114 | ...do..... | July 20 | 20 | 168 | July 26 | ...do..... | 23 |
| 115 | ...do..... | ...do..... | 20 | 169 | ...do..... | Aug. 20 | 25 |
| 116 | ...do..... | ...do..... | 20 | 170 | July 31 | Aug. 17 | 17 |
| 117 | ...do..... | July 22 | 22 | 171 | Aug. 3 | ...do..... | 14 |
| 118 | ...do..... | ...do..... | 22 | 172 | ...do..... | ...do..... | 22 |
| 119 | July 1 | July 20 | 19 | 173 | Aug. 10 | Aug. 25 | 20 |
| 120 | ...do..... | July 21 | 20 | 174 | Aug. 11 | Aug. 30 | 13 |
| 121 | ...do..... | ...do..... | 20 | 175 | ...do..... | Aug. 24 | 16 |
| 122 | ...do..... | July 22 | 21 | 176 | ...do..... | Aug. 27 | 17 |
| 123 | ...do..... | ...do..... | 21 | 177 | Aug. 12 | ...do..... | 15 |
| 124 | July 2 | July 21 | 19 | 178 | Aug. 16 | Aug. 31 | 15 |
| 125 | ...do..... | July 22 | 20 | 179 | ...do..... | Sept. 1 | 16 |
| 126 | ...do..... | July 23 | 21 | 180 | Aug. 17 | Sept. 3 | 17 |
| 127 | ...do..... | ...do..... | 21 | 181 | ...do..... | ...do..... | 17 |
| 128 | July 3 | ...do..... | 20 | 182 | ...do..... | ...do..... | 17 |

Summarizing the above records we find the earliest pupa on June 25 and the latest August 17. The first adult emerged on July 13 and the last September 3. The shortest pupal period was 13 days, the longest 31, and the average 19.84 days. No record with regard to the sex of larvæ or adults was taken. Table IV shows the length of the pupal stage summarized.

TABLE IV.—*Pupæ of the first brood. Variations in the pupal period. Summary of Table III.*

| Number of pupæ. | Days. | Number of pupæ. | Days. | Number of pupæ. | Days. | Number of pupæ. | Days. |
|---|---|---|---|---|---|---|---|
| 1 | 13 | 31 | 19 | 4 | 24 | 1 | 29 |
| 1 | 14 | 39 | 20 | 3 | 25 | .......... | 30 |
| 3 | 15 | 35 | 21 | .......... | 26 | 1 | 31 |
| 2 | 16 | 13 | 22 | .......... | 27 | | |
| 8 | 17 | 6 | 23 | .......... | 28 | 182 | |
| 34 | 18 | | | | | | |

FIRST BROOD OF MOTHS.

*Time of emergence.*—Larvæ and pupæ were collected from under bands on apple trees on June 21, June 28, July 6, and thereafter twice a week until September 20, when the last collection was made. Figure 27 shows graphically the adult emergence of the first-brood moths from this material and figure 28 the percentage which passed the winter in the larval stage. They also record the daily emergence of these moths from July 12, 1909, to June 9, 1910. Table V shows the adult emergence for the total number of moths of the first brood, including both those from the general band record and those from the individual pupation records.

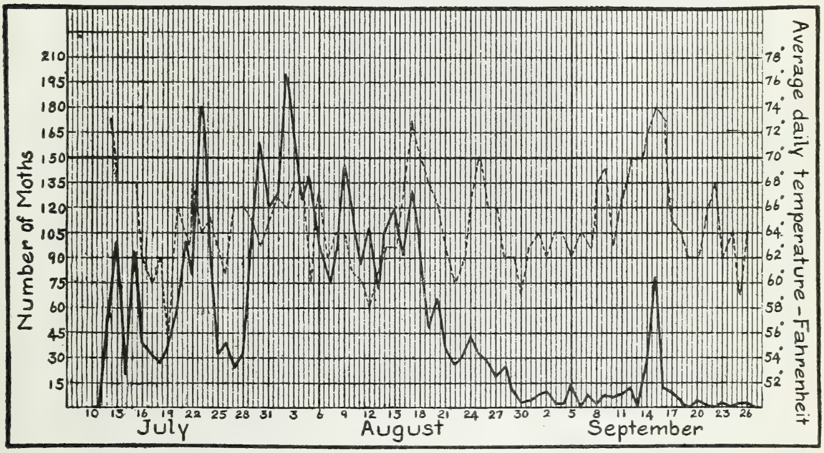

FIG. 27.—Diagram showing emergence of moths, derived from band-record material collected in 1909. (Original.)

TABLE V.—*Moths of the first brood; total emergence.*

| Date. | Number emerged. | Date. | Number emerged. | Date. | Number emerged. | Date. | Number emerged. |
|---|---|---|---|---|---|---|---|
| July 12 | 55 | July 31 | 124 | Aug. 19 | 48 | Sept. 8 | 2 |
| July 13 | 111 | Aug. 1 | 130 | Aug. 20 | 68 | Sept. 9 | 8 |
| July 14 | 27 | Aug. 2 | 199 | Aug. 21 | 38 | Sept. 10 | 7 |
| July 15 | 101 | Aug. 3 | 168 | Aug. 22 | 27 | Sept. 11 | 8 |
| July 16 | 68 | Aug. 4 | 130 | Aug. 23 | 30 | Sept. 12 | 13 |
| July 17 | 60 | Aug. 5 | 144 | Aug. 24 | 45 | Sept. 14 | 28 |
| July 18 | 28 | Aug. 6 | 101 | Aug. 25 | 34 | Sept. 15 | 78 |
| July 19 | 56 | Aug. 7 | 76 | Aug. 26 | 29 | Sept. 16 | 14 |
| July 20 | 65 | Aug. 8 | 96 | Aug. 27 | 22 | Sept. 17 | 10 |
| July 21 | 107 | Aug. 9 | 148 | Aug. 28 | 25 | Sept. 18 | 1 |
| July 22 | 87 | Aug. 10 | 114 | Aug. 29 | 12 | Sept. 20 | 3 |
| July 23 | 183 | Aug. 11 | 87 | Aug. 30 | 4 | Sept. 23 | 1 |
| July 24 | 105 | Aug. 12 | 108 | Aug. 31 | 5 | Sept. 25 | 2 |
| July 25 | 32 | Aug. 13 | 74 | Sept. 1 | 8 | Sept. 26 | 2 |
| July 26 | 41 | Aug. 14 | 106 | Sept. 2 | 9 | | |
| July 27 | 25 | Aug. 15 | 119 | Sept. 3 | 6 | | 4,359 |
| July 28 | 35 | Aug. 16 | 92 | Sept. 4 | 2 | | |
| July 29 | 101 | Aug. 17 | 134 | Sept. 5 | 15 | | |
| July 30 | 160 | Aug. 18 | 103 | Sept. 7 | 8 | | |

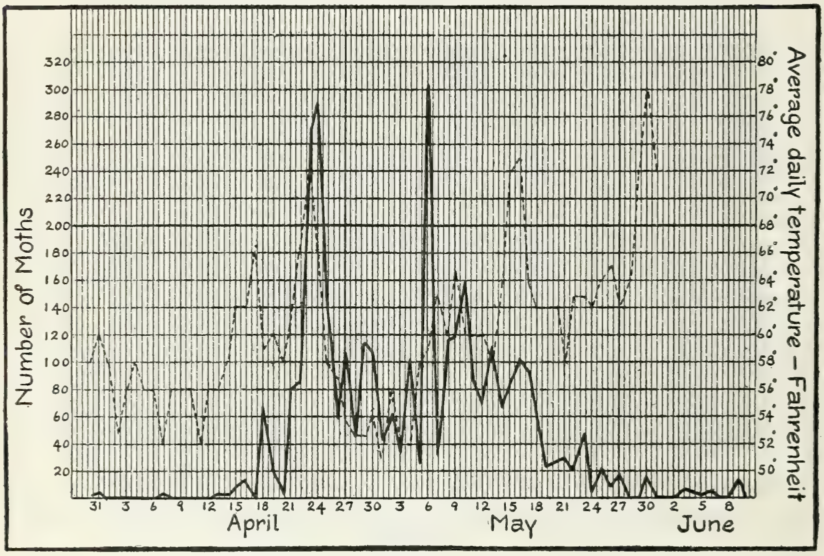

FIG. 28.—Diagram showing emergence of moths, derived from band-record material collected in 1909. (Original.)

It is therefore apparent that maximum emergence took place during the period of from July 13 to August 18, and that thereafter the emergence was drawn out all through the balance of August and up to September 26.

## SECOND GENERATION.

### SECOND BROOD OF EGGS.

No further observations on the life history of the codling moth were taken in 1909.

## SEASONAL-HISTORY STUDIES OF 1910.

### SPRING BROOD OF PUPÆ.

*Time of pupation.*—The earliest pupation observed during the spring of 1910 in the breeding jars was on March 3 and the latest pupation April 25. Considering the time when the first adult emerged on March 30, and adding the average length of the pupal stage, or 40.7 days, the earliest pupation must have taken place about February 18. As the latest adult of the spring brood of moths emerged on June 9, the last overwintering larvæ must have pupated about May 1.

Pupæ were therefore in evidence from February 18 to June 9, a period of 111 days.

Figure 29 shows when the first, last, and maximum pupation took place in the rearing cages, as well as the daily mean temperature, and that the overwintering larvæ pupated from March 3 until April 25. Most of the larvæ pupated during the period from March 8 to 25.

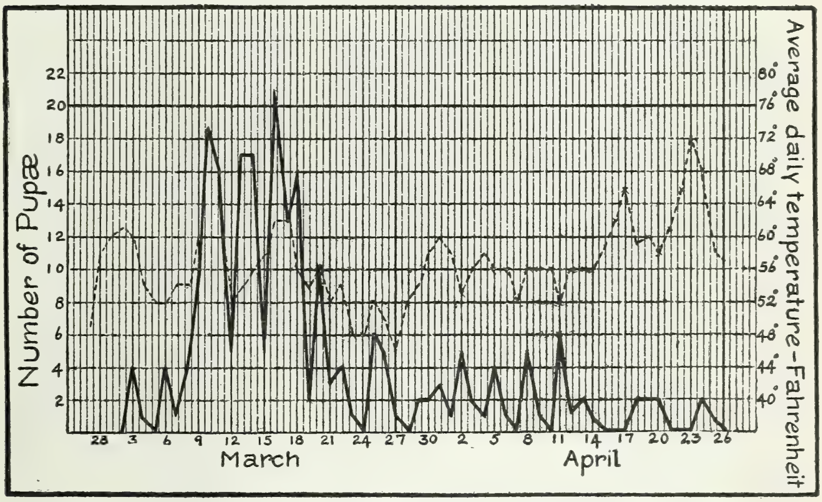

FIG. 29.—Diagram showing time of pupation of spring brood of pupæ, 1910. (Original.)

An examination of figure 29 shows that the sudden increase in daily mean temperature after February 20 probably started overwintering larvæ pupating. The high daily mean temperature from March 8 to 20 explains the maximum time of pupation, and shows that a drop or increase of 5 degrees in mean temperature usually influenced accordingly the number of larvæ pupating. The period of low mean temperature from March 20 to 27 stopped pupation to some extent, but it was started again in the remaining days of March and in early April. By this time practically all of the larvæ had pupated, and the warm period following has no bearing on the time of pupation.

*Length of spring pupal stage.*—Records were obtained on 229 pupæ which were kept in vials under natural conditions (see Table VI):

TABLE VI.—*Spring brood of pupæ. Length of the pupal period for overwintering larvæ collected during 1909 on banded trees.*

| No. of individual. | Sex of larva. | Date of— | | Sex of moth. | Length of pupal stage. | No. of individual. | Sex of larva. | Date of— | | Sex of moth. | Length of pupal stage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pupation. | Emergence. | | | | | Pupation. | Emergence. | | |
| | | | | | *Days.* | | | | | | *Days.* |
| 1 | ♂ | Mar. 3 | Apr. 16 | ♂ | 44 | 71 | ...... | Mar. 13 | Apr. 24 | ...... | 42 |
| 2 | ♂ | ...do..... | ...do..... | ♂ | 44 | 72 | ...... | ...do..... | ...do..... | ...... | 42 |
| 3 | ♂ | ...do..... | ...do..... | ♂ | 44 | 73 | ...... | ...do..... | ...do..... | ...... | 42 |
| 4 | ♀ | ...do..... | Apr. 18 | ♀ | 46 | 74 | ...... | ...do..... | ...do..... | ...... | 42 |
| 5 | ...... | Mar. 4 | Apr. 19 | ...... | 46 | 75 | ♂ | ...do..... | Apr. 25 | ♂ | 43 |
| 6 | ♂ | Mar. 5 | May 9 | ♂ | 34 | 76 | ♀ | ...do..... | ...do..... | ♀ | 43 |
| 7 | ♂ | Mar. 6 | Apr. 19 | ♂ | 44 | 77 | ♂ | ...do..... | Apr. 23 | ♂ | 44 |
| 8 | ♀ | ...do..... | Apr. 20 | ♀ | 45 | 78 | ...... | ...do..... | Apr. 28 | ...... | 41 |
| 9 | ♂ | ...do..... | Apr. 22 | ♂ | 47 | 79 | ♀ | ...do..... | Apr. 23 | ♀ | 41 |
| 10 | ♂ | ...do..... | ...do..... | ♂ | 47 | 80 | ♀ | ...do..... | Apr. 25 | ♀ | 43 |
| 11 | ♀ | Mar. 7 | ...do..... | ♀ | 46 | 81 | ...... | ...do..... | ...do..... | ...... | 43 |
| 12 | ...... | Mar. 8 | ...do..... | ...... | 45 | 82 | ♂ | ...do..... | ...do..... | ♂ | 43 |
| 13 | ...... | ...do..... | ...do..... | ...... | 45 | 83 | ♀ | ...do..... | ...do..... | ♀ | 43 |
| 14 | ...... | ...do..... | ...do..... | ...... | 45 | 84 | ♂ | Mar. 14 | Apr. 24 | ♂ | 41 |
| 15 | ...... | ...do..... | May 9 | ...... | 31 | 85 | ♀ | ...do..... | ...do..... | ♀ | 41 |
| 16 | ...... | ...do..... | Apr. 21 | ...... | 44 | 86 | ♂ | ...do..... | ...do..... | ♂ | 41 |
| 17 | ♂ | Mar. 9 | Apr. 22 | ♂ | 44 | 87 | ♂ | ...do..... | ...do..... | ♂ | 41 |
| 18 | ...... | ...do..... | Apr. 27 | ...... | 49 | 88 | ...... | ...do..... | Apr. 23 | ...... | 40 |
| 19 | ♀ | ...do..... | Apr. 22 | ♀ | 44 | 89 | ...... | ...do..... | ...do..... | ...... | 40 |
| 20 | ♂ | ...do..... | Apr. 23 | ♂ | 45 | 90 | ♀ | ...do..... | Apr. 25 | ♀ | 42 |
| 21 | ♀ | ...do..... | ...do..... | ♀ | 45 | 91 | ♀ | ...do..... | Apr. 24 | ♀ | 41 |
| 22 | ♀ | ...do..... | Apr. 22 | ♀ | 44 | 92 | ♂ | ...do..... | Apr. 27 | ♂ | 44 |
| 23 | ...... | ...do..... | ...do..... | ...... | 44 | 93 | ♀ | ...do..... | Apr. 24 | ♀ | 41 |
| 24 | ♀ | ...do..... | Apr. 23 | ♀ | 45 | 94 | ♀ | ...do..... | Apr. 25 | ♀ | 42 |
| 25 | ...... | ...do..... | ...do..... | ...... | 45 | 95 | ...... | ...do..... | Apr. 24 | ...... | 41 |
| 26 | ♂ | ...do..... | ...do..... | ♂ | 45 | 96 | ...... | ...do..... | ...do..... | ...... | 41 |
| 27 | ♀ | Mar. 10 | Apr. 24 | ♀ | 45 | 97 | ♂ | ...do..... | ...do..... | ♂ | 41 |
| 28 | ...... | ...do..... | Apr. 23 | ...... | 44 | 98 | ♀ | ...do..... | Apr. 25 | ♀ | 42 |
| 29 | ♀ | ...do..... | ...do..... | ♀ | 44 | 99 | ...... | ...do..... | Apr. 23 | ...... | 40 |
| 30 | ♂ | ...do..... | ...do..... | ♂ | 44 | 100 | ♂ | ...do..... | ...do..... | ♂ | 40 |
| 31 | ...... | ...do..... | Apr. 21 | ...... | 42 | 101 | ♂ | Mar. 15 | Apr. 24 | ♂ | 40 |
| 32 | ...... | ...do..... | Apr. 23 | ...... | 44 | 102 | ♂ | ...do..... | ...do..... | ♂ | 40 |
| 33 | ♀ | ...do..... | Apr. 24 | ♀ | 45 | 103 | ♀ | ...do..... | Apr. 25 | ♀ | 41 |
| 34 | ...... | ...do..... | ...do..... | ...... | 45 | 104 | ...... | ...do..... | ...do..... | ...... | 41 |
| 35 | ♀ | ...do..... | ...do..... | ♀ | 45 | 105 | ♀ | ...do..... | Apr. 27 | ♀ | 43 |
| 36 | ♀ | ...do..... | Apr. 23 | ...... | 44 | 106 | ...... | Mar. 16 | Apr. 25 | ...... | 40 |
| 37 | ...... | ...do..... | ...do..... | ...... | 44 | 107 | ♂ | ...do..... | ...do..... | ♀ | 40 |
| 38 | ♂ | ...do..... | Apr. 21 | ♂ | 42 | 108 | ♀ | ...do..... | ...do..... | ♀ | 40 |
| 39 | ♀ | ...do..... | Apr. 23 | ♀ | 44 | 109 | ♀ | ...do..... | Apr. 27 | ♀ | 42 |
| 40 | ...... | ...do..... | Apr. 24 | ♂ | 43 | 110 | ...... | ...do..... | May 16 | ...... | 61 |
| 41 | ...... | ...do..... | Apr. 23 | ...... | 44 | 111 | ♂ | ...do..... | Apr. 27 | ♂ | 42 |
| 42 | ♂ | ...do..... | ...do..... | ♂ | 44 | 112 | ♀ | ...do..... | Apr. 26 | ♀ | 41 |
| 43 | ♂ | ...do..... | ...do..... | ♂ | 44 | 113 | ♂ | ...do..... | Apr. 25 | ♂ | 40 |
| 44 | ♀ | ...do..... | Apr. 21 | ♀ | 42 | 114 | ♀ | ...do..... | Apr. 28 | ♀ | 43 |
| 45 | ...... | ...do..... | Apr. 23 | ...... | 44 | 115 | ...... | ...do..... | Apr. 27 | ...... | 42 |
| 46 | ♂ | Mar. 11 | Apr. 24 | ♂ | 44 | 116 | ♀ | ...do..... | ...do..... | ♀ | 42 |
| 47 | ♂ | ...do..... | Apr. 23 | ♂ | 43 | 117 | ...... | ...do..... | Apr. 25 | ...... | 40 |
| 48 | ♀ | ...do..... | ...do..... | ♀ | 43 | 118 | ♀ | ...do..... | Apr. 28 | ♀ | 43 |
| 49 | ♂ | ...do..... | ...do..... | ♂ | 43 | 119 | ♀ | ...do..... | Apr. 25 | ♀ | 40 |
| 50 | ...... | ...do..... | ...do..... | ...... | 43 | 120 | ...... | ...do..... | Apr. 24 | ...... | 39 |
| 51 | ...... | ...do..... | Apr. 24 | ...... | 44 | 121 | ...... | ...do..... | Apr. 25 | ...... | 40 |
| 52 | ...... | ...do..... | Apr. 21 | ...... | 41 | 122 | ♂ | ...do..... | ...do..... | ♂ | 40 |
| 53 | ...... | ...do..... | ...do..... | ...... | 41 | 123 | ...... | ...do..... | ...do..... | ...... | 40 |
| 54 | ...... | ...do..... | Apr. 23 | ...... | 43 | 124 | ♂ | ...do..... | Apr. 27 | ♂ | 42 |
| 55 | ♀ | ...do..... | Apr. 24 | ♀ | 44 | 125 | ...... | ...do..... | Apr. 25 | ...... | 40 |
| 56 | ...... | ...do..... | Apr. 23 | ...... | 43 | 126 | ♂ | Mar. 17 | Apr. 28 | ♂ | 42 |
| 57 | ...... | ...do..... | Apr. 24 | ...... | 44 | 127 | ♂ | ...do..... | Apr. 25 | ♂ | 39 |
| 58 | ♀ | ...do..... | ...do..... | ♀ | 44 | 128 | ♂ | ...do..... | Apr. 27 | ♂ | 41 |
| 59 | ♀ | ...do..... | Apr. 23 | ♀ | 43 | 129 | ...... | ...do..... | Apr. 25 | ...... | 39 |
| 60 | ...... | ...do..... | ...do..... | ...... | 43 | 130 | ♀ | ...do..... | May 2 | ♀ | 46 |
| 61 | ♂ | ...do..... | Apr. 24 | ♂ | 44 | 131 | ♂ | ...do..... | Apr. 29 | ♂ | 43 |
| 62 | ♂ | Mar. 12 | Apr. 23 | ♂ | 42 | 132 | ...... | ...do..... | Apr. 28 | ...... | 42 |
| 63 | ...... | ...do..... | ...do..... | ...... | 42 | 133 | ♀ | ...do..... | Apr. 29 | ♀ | 43 |
| 64 | ♀ | ...do..... | Apr. 24 | ♀ | 43 | 134 | ♂ | ...do..... | Apr. 27 | ♂ | 41 |
| 65 | ♀ | ...do..... | ...do..... | ...... | 43 | 135 | ...... | ...do..... | Apr. 30 | ...... | 40 |
| 66 | ♂ | ...do..... | ...do..... | ♂ | 43 | 136 | ...... | ...do..... | ...do..... | ...... | 44 |
| 67 | ♂ | Mar. 13 | ...do..... | ♂ | 42 | 137 | ...... | ...do..... | Apr. 28 | ...... | 42 |
| 68 | ♀ | ...do..... | ...do..... | ♀ | 42 | 138 | ♀ | ...do..... | Apr. 29 | ♀ | 43 |
| 69 | ♀ | ...do..... | ...do..... | ♀ | 42 | 139 | ♀ | Mar. 18 | ...do..... | ♀ | 42 |
| 70 | ...... | ...do..... | Apr. 25 | ...... | 43 | 140 | ...... | ...do..... | Apr. 27 | ...... | 40 |

TABLE VI.—*Spring brood of pupæ. Length of the pupal period for overwintering larvæ collected during 1909 on banded trees*—Continued.

| No. of individual. | Sex of larva. | Date of— | | Sex of moth. | Length of pupal stage. | No. of individual. | Sex of larva. | Date of— | | Sex of moth. | Length of pupal stage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pupation. | Emergence. | | | | | Pupation. | Emergence. | | |
| | | | | | *Days.* | | | | | | *Days.* |
| 141 | ♀ | Mar. 18 | Apr. 29 | ♀ | 42 | 186 | | Mar. 27 | May 4 | | 38 |
| 142 | | do | do | | 42 | 187 | ♂ | Mar. 29 | do | ♂ | 36 |
| 143 | | do | Apr. 28 | | 41 | 188 | | do | May 5 | | 37 |
| 144 | ♀ | do | do | ♀ | 41 | 189 | ♀ | Mar. 30 | May 6 | ♀ | 37 |
| 145 | ♂ | do | do | ♂ | 41 | 190 | ♀ | do | May 5 | ♀ | 36 |
| 146 | | do | Apr. 25 | | 38 | 191 | | Mar. 31 | May 6 | | 36 |
| 147 | | do | May 4 | | 47 | 192 | ♂ | do | May 7 | ♀ | 37 |
| 148 | ♂ | do | Apr. 28 | ♂ | 41 | 193 | ♂ | do | May 6 | ♂ | 36 |
| 149 | ♀ | do | May 2 | ♀ | 45 | 194 | ♀ | do | May 8 | ♀ | 38 |
| 150 | ♂ | do | Apr. 29 | ♂ | 42 | 195 | ♀ | Apr. 1 | May 7 | ♀ | 36 |
| 151 | ♀ | do | May 2 | ♀ | 45 | 196 | ♀ | Apr. 2 | May 9 | ♀ | 37 |
| 152 | ♂ | do | Apr. 28 | ♂ | 41 | 197 | ♂ | do | May 7 | ♂ | 35 |
| 153 | ♂ | do | Apr. 30 | ♂ | 43 | 198 | ♂ | do | May 9 | ♂ | 37 |
| 154 | | do | May 3 | | 46 | 199 | | do | May 7 | | 35 |
| 155 | ♀ | Mar. 19 | do | ♀ | 45 | 200 | ♀ | do | May 9 | ♀ | 37 |
| 156 | ♀ | do | do | ♀ | 45 | 201 | ♀ | Apr. 3 | do | ♀ | 36 |
| 157 | ♀ | Mar. 20 | do | ♀ | 44 | 202 | ♂ | do | May 10 | ♂ | 37 |
| 158 | | do | do | | 44 | 203 | | Apr. 4 | May 6 | | 32 |
| 159 | ♂ | do | May 2 | ♂ | 43 | 204 | ♂ | Apr. 5 | May 9 | ♂ | 34 |
| 160 | ♀ | do | May 3 | ♀ | 44 | 205 | ♀ | do | May 10 | ♀ | 35 |
| 161 | ♀ | do | do | ♀ | 44 | 206 | ♀ | do | May 8 | ♀ | 30 |
| 162 | | do | Apr. 29 | | 40 | 207 | ♀ | Apr. 6 | May 10 | ♀ | 34 |
| 163 | ♀ | do | May 3 | ♀ | 44 | 208 | | Apr. 8 | do | | 32 |
| 164 | ♂ | do | May 2 | ♂ | 43 | 209 | ♂ | do | do | ♂ | 32 |
| 165 | ♂ | do | Apr. 30 | ♂ | 41 | 210 | | do | May 11 | | 33 |
| 166 | | do | do | | 41 | 211 | ♀ | do | May 10 | ♀ | 32 |
| 167 | ♂ | Mar. 21 | do | ♂ | 40 | 212 | ♀ | Apr. 9 | May 13 | ♀ | 34 |
| 168 | ♂ | do | May 4 | ♂ | 44 | 213 | ♂ | Apr. 11 | May 14 | ♂ | 33 |
| 169 | ♂ | do | Apr. 30 | ♂ | 40 | 214 | ♀ | do | May 13 | ♀ | 32 |
| 170 | ♂ | Mar. 22 | Apr. 29 | ♂ | 38 | 215 | ♀ | do | May 14 | ♀ | 33 |
| 171 | | do | May 4 | | 43 | 216 | | do | May 11 | | 30 |
| 172 | ♂ | do | Apr. 24 | ♂ | 41 | 217 | ♀ | do | May 14 | ♀ | 33 |
| 173 | ♂ | do | Apr. 29 | ♂ | 38 | 218 | ♀ | do | May 12 | ♀ | 32 |
| 174 | ♀ | Mar. 23 | May 3 | ♀ | 41 | 219 | ♂ | Apr. 12 | do | ♂ | 30 |
| 175 | ♀ | Mar. 25 | Apr. 30 | ♀ | 36 | 220 | ♀ | Apr. 13 | May 15 | ♀ | 32 |
| 176 | ♀ | do | May 15 | ♀ | 51 | 221 | | do | May 13 | | 30 |
| 177 | | do | May 2 | | 38 | 222 | ♂ | Apr. 14 | do | ♂ | 29 |
| 178 | ♀ | do | May 6 | ♀ | 42 | 223 | ♀ | Apr. 18 | May 17 | ♀ | 29 |
| 179 | | do | May 4 | | 40 | 224 | | do | do | | 29 |
| 180 | | do | Apr. 30 | | 36 | 225 | | Apr. 20 | May 20 | | 30 |
| 181 | ♀ | Mar. 26 | May 4 | ♀ | 39 | 226 | ♀ | do | do | ♀ | 30 |
| 182 | ♀ | do | Apr. 30 | ♀ | 35 | 227 | | Apr. 24 | May 24 | | 30 |
| 183 | ♀ | do | May 3 | ♀ | 39 | 228 | ♀ | do | May 25 | ♀ | 31 |
| 184 | ♀ | do | May 2 | ♀ | 37 | 229 | ♂ | Apr. 25 | May 24 | ♂ | 29 |
| 185 | ♀ | do | May 3 | ♀ | 38 | | | | | | |

The variations in the length of the pupal periods, as shown in Table VI, extended from 29 to 61 days.

TABLE VII.—*Spring brood of pupæ. Variations in the length of the pupal period for 229 pupæ as recorded in Table VI.*

| Number of pupæ. | Days. | Number of pupæ. | Days. | Number of pupæ. | Days. | Number of pupæ. | Days. |
|---|---|---|---|---|---|---|---|
| 4 | 29 | 4 | 35 | 28 | 41 | 3 | 47 |
| 6 | 30 | 8 | 36 | 28 | 42 | 1 | 49 |
| 2 | 31 | 8 | 37 | 28 | 43 | 1 | 51 |
| 7 | 32 | 8 | 38 | 34 | 44 | 1 | 61 |
| 5 | 33 | 4 | 39 | 18 | 45 | | |
| 4 | 34 | 22 | 40 | 5 | 46 | | |

An examination of Table VI shows that larvæ pupating in March usually required several days longer for the pupal periods than larvæ pupating in April.

Table VIII shows the summary of observations recorded in Table VI and that the average length of the pupal period was 40.7 days for the 229 pupæ.

Table VIII.—*Spring brood of pupæ. Summary of pupal periods of Table VI.*

| Observations. | Days. |
|---|---|
| Maximum | 61 |
| Minimum | 29 |
| Average | 40.7 |

*Comparative length of pupal periods of male and female larvæ.*—An attempt was made to ascertain the sex of the future moth while in the larval state, by the occurrence of two black spots on the dorsum of one of the posterior abdominal segments, the presence of which indicated a male. Records were kept on each individual that could be observed well in its cocoon, and in each instance the moth issued true to the sex ascribed to it while in the larval state.

In comparing the total pupal periods for 64 males and 87 females, the average length of the pupal stage for males was found to be 40.5 days and that of the female to be 40.6 days. This difference was not sufficient to warrant any conclusion during the 1910 season as to the respective lengths of the pupal periods of the males in comparison with that of the females.

*Temperature conditions.*—The temperature conditions influencing the pupal periods of the spring brood of pupæ are summarized in Table IX:

Table IX.—*Spring brood of pupæ. Temperature conditions influencing the pupal period.*

|  | Maximum. | Minimum. | Mean. | Departure from normal. |
|---|---|---|---|---|
|  | °*F.* | °*F.* | °*F.* | °*F.* |
| March | 66.2 | 44.5 | 55.4 | +1.7 |
| April | 70.2 | 46.0 | 58.1 | +1.4 |
| May | 75.9 | 48.7 | 62.3 | +1.6 |
| Average | 70.7 | 46.4 | 58.6 |  |

## SPRING BROOD OF MOTHS.

*Time of emergence of moths in the spring.*—Figure 2 shows graphically the time of emergence and the relative abundance of moths of the spring brood with the corresponding daily mean temperature in degrees Fahrenheit. The records for these observations are given in Table X.

TABLE X.—*Emergence of spring moths from wintering material collected on banded trees during 1909.*

| Date. | Number of moths. | Date. | Number of moths. | Date. | Number of moths. | Date. | Number of moths. |
|---|---|---|---|---|---|---|---|
| Mar. 30 | 1 | Apr. 17 | 0 | May 5 | 28 | May 23 | 56 |
| Mar. 31 | 2 | Apr. 18 | 60 | May 6 | 329 | May 24 | 5 |
| Apr. 1 | 0 | Apr. 19 | 23 | May 7 | 36 | May 25 | 28 |
| Apr. 2 | 0 | Apr. 20 | 8 | May 8 | 127 | May 26 | 12 |
| Apr. 3 | 0 | Apr. 21 | 87 | May 9 | 136 | May 27 | 21 |
| Apr. 4 | 0 | Apr. 22 | 99 | May 10 | 185 | May 28 | 0 |
| Apr. 5 | 0 | Apr. 23 | 307 | May 11 | 97 | May 29 | 0 |
| Apr. 6 | 0 | Apr. 24 | 333 | May 12 | 84 | May 30 | 27 |
| Apr. 7 | 1 | Apr. 25 | 152 | May 13 | 127 | May 31 | 0 |
| Apr. 8 | 0 | Apr. 26 | 61 | May 14 | 74 | June 1 | 0 |
| Apr. 9 | 0 | Apr. 27 | 125 | May 15 | 102 | June 2 | 0 |
| Apr. 10 | 0 | Apr. 28 | 58 | May 16 | 122 | June 3 | 8 |
| Apr. 11 | 0 | Apr. 29 | 130 | May 17 | 118 | June 4 | 2 |
| Apr. 12 | 0 | Apr. 30 | 121 | May 18 | 77 | June 5 | 1 |
| Apr. 13 | 1 | May 1 | 45 | May 19 | 25 | June 6 | 6 |
| Apr. 14 | 1 | May 2 | 76 | May 20 | 30 | June 7 | 0 |
| Apr. 15 | 7 | May 3 | 48 | May 21 | 32 | June 8 | 0 |
| Apr. 16 | 18 | May 4 | 111 | May 22 | 21 | June 9 | 20 |

The emergence of the first moths on March 30 and 31 was undoubtedly caused by the sudden rise in mean temperature about this time, as will be seen from figure 1. Also the period of low mean temperature during the first 12 days of April stopped emergence to a minimum. A rise in temperature from April 12 to 18 brought forth moths again, and the high period of mean temperature about April 22 to 24 caused the first absolute maximum of emergence, then a drop in temperature and a corresponding cessation of emergence, and finally the second absolute maximum emergence on May 6, which was caused by high mean temperature about that period and the rest of the month. After May 18 practically all of the moths had emerged and no further conclusions could be drawn of the influence of temperature on the emergence of spring-brood moths. Most of the moths emerged during the period from April 15 to May 20 and the maximum period thus embraced about 35 days. The whole period of emergence of spring-brood moths extended from March 30 to June 9, a period of 72 days.

*Time of emergence of moths in the spring versus the time wintering larvæ leave the fruit the preceding year.*—In Table XI is given a detailed account of the band collections of 1909, including the dates of collection, relative number of pupæ and larvæ, daily emergence of the first brood moths for that year (1909), and the daily emergence of the spring-brood moths which came from the overwintering larvæ, the latter being both first and second brood larvæ of 1909. In Table XI is given also the relative percentage of moths emerging from each separate band collection for the years 1909 and 1910, including totals for each year and a summary of the total moths emerging for both years. As previously recorded by Mr. Hammar,[1] the time the larvæ leave the fruit in the fall has no bearing upon the time of emergence of the moths in the following spring; in fact, some of the larvæ which left the fruit the latest in the fall of 1909 emerged as moths the earliest in the spring of 1910. The division line between broods probably occurred about August 12 to 16, and by examining the table of the emergence record of 1910 no difference can be seen between the respective dates of emergence of the moths.

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[1] Bureau of Entomology, Bul. No. 80, Part VI.

*Relative percentage of larvæ wintering from band material and percentage emerging as first-brood moths the year the larvæ were collected.*—An examination of Table XI shows that 65.3 per cent was the highest number that emerged in 1909 for any single band collection and 6 per cent the lowest. No moths emerged in 1909 from band collections later than August 31. Of the total number of pupæ and larvæ collected from all the bands for the entire season only 28.31 per cent emerged as first-brood moths for the year 1909. One curious fact of the percentages that emerged in 1909 from each band collection during that year was the sudden rise in percentage to 39.6 for the lot collected August 19, after the percentage column had begun to dwindle to smaller proportions. It will be seen from a glance at the table that the moths emerged from this collection from September 11 to 16 and this may be explained by the very high mean temperature during this period. Just why the high temperature influenced this one collection and none of the earlier or later collections is difficult to explain, except that this particular collection was the first important collection of second-brood larvæ.

A very unfortunate thing happened during the winter of 1909–10, in that the first three jars and also jar C–10 were nearly filled with water and consequently all of the overwintering larvæ were drowned before being noticed. This caused to a great extent the small total percentage emerging in 1910, or 21.25 per cent, which might have been 30 or 35 per cent.

The total percentage emerging for both years 1909–10 from the total amount of larvæ and pupæ collected was 49.56 per cent, the remainder having died naturally or were in the four jars filled with water. It will be noticed that the highest total percentage emerging for both years from any separate band collection was 88.4 per cent and was from the previously mentioned collection on August 19, 1909.

TABLE XI.—*Adult emergence of the first and spring broods from band material collected in 1909.*

| Jar No. | Date of collection. | Number collected. | | Total. | Emergence. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Larvæ. | Pupæ. | | 1909. | | 1910. | | 1909–10. | |
| | | | | | *Number.* | *Per cent.* | *Number.* | *Per cent.* | *Number.* | *Per cent.* |
| | 1909. | | | | | | | | | |
| C–3 | June 21.... | 1,602 | 215 | 1,817 | 403 | 23.8 | ........ | ........ | 403 | 23.8 |
| C–4–5 | June 28.... | 2,276 | 79 | 2,355 | 678 | 28.8 | ........ | ........ | 678 | 28.8 |
| C–7 | July 6..... | 946 | 159 | 1,105 | 722 | 65.3 | ........ | ........ | 722 | 65.3 |
| C–8 | July 9..... | 804 | 93 | 897 | 427 | 47.6 | 122 | 13.6 | 549 | 61.2 |
| C–9 | July 12.... | 761 | 59 | 820 | 295 | 35.9 | 121 | 14.7 | 416 | 50.6 |
| C–10 | July 15.... | 885 | 68 | 953 | 496 | 52.0 | ........ | ........ | 496 | 52.0 |
| C–11 | July 19.... | 919 | 48 | 967 | 433 | 44.7 | 141 | 14.6 | 574 | 59.3 |
| C–12 | July 22.... | 536 | 37 | 573 | 260 | 45.3 | 74 | 11.1 | 334 | 56.4 |
| C–13 | July 26.... | 505 | 30 | 535 | 148 | 26.5 | 143 | 26.5 | 291 | 53.0 |
| C–14 | July 29.... | 350 | 22 | 372 | 79 | 21.2 | 133 | 35.7 | 212 | 56.9 |
| C–15 | Aug. 2..... | 297 | 22 | 319 | 48 | 15.0 | 115 | 36.0 | 163 | 51.0 |
| C–16 | Aug. 5..... | 180 | 16 | 196 | 4 | 2.0 | 42 | 21.4 | 46 | 23.4 |
| C–18 | Aug. 9..... | 185 | 7 | 192 | 26 | 13.5 | 47 | 24.4 | 73 | 37.9 |
| C–19 | Aug. 12.... | 115 | 10 | 125 | 9 | 7.2 | 82 | 65.6 | 91 | 72.8 |
| C–21 | Aug. 16.... | 112 | 4 | 116 | 18 | 15.5 | 55 | 48.2 | 73 | 63.7 |
| C–22 | Aug. 19.... | 262 | 2 | 264 | 105 | 39.6 | 129 | 48.8 | 234 | 88.4 |
| C–23 | Aug. 23.... | 383 | 0 | 383 | 18 | 4.6 | 193 | 50.4 | 211 | 55.0 |
| C–24 | Aug. 26.... | 403 | 3 | 406 | 5 | 1.2 | 223 | 54.9 | 228 | 56.1 |
| C–25 | Aug. 31.... | 477 | 4 | 481 | 3 | .6 | 267 | 55.5 | 270 | 56.1 |
| C–26 | Sept. 2.... | 371 | 4 | 375 | ........ | ........ | 210 | 56.0 | 210 | 56.0 |
| C–27 | Sept. 6.... | 580 | 0 | 580 | ........ | ........ | 257 | 44.3 | 257 | 44.3 |
| C–28 | Sept. 9.... | 381 | 0 | 381 | ........ | ........ | 258 | 66.9 | 258 | 66.9 |
| C–29 | Sept. 13... | 253 | 0 | 253 | ........ | ........ | 328 | 72.4 | 328 | 72.4 |
| C–30 | Sept. 16... | 359 | 1 | 360 | ........ | ........ | 157 | 43.6 | 157 | 43.6 |
| C–31 | Sept. 20... | 290 | 0 | 290 | ........ | ........ | 116 | 40.0 | 116 | 40.0 |
| | Total.. | 14,232 | 883 | 15,115 | 4,177 | 27.63 | 3,213 | 21.25 | 7,390 | 48.88 |

*Time during the day when moths emerged.*—No tabulated record was kept to show the time during the day when most of the moths emerged, but observations showed that they issued in numbers after 4 p. m. and supposedly during the night. Few emerged during the period from morning after 9 o'clock until in the evening. The emergence record was therefore usually taken each morning before 9 a. m. and included moths of the evening and night before. This seems at variance with the records obtained in 1911.

*Period of oviposition.*—The first moths that appeared the latter part of March failed to oviposit since only a few individuals had appeared until April 18. No difficulty was experienced in obtaining eggs in confinement when a number of moths were placed in a cage at a time. No eggs could be obtained from single pairs of spring-brood moths as was possible later with those of the first brood and hence no data was obtained as to the number of eggs a single female can deposit.

The first eggs were obtained April 26 or about from 3 to 4 days after moths began to emerge in numbers. The period of low mean temperature from April 26 to May 5 (see fig. 28) caused very few eggs to be deposited, but by May 7 and from then on until the end of the month large numbers were obtained. Oviposition in the field probably extended from April 10 to June 20 (about 10 days after the last moth appeared), or a period of about 80 days, this giving a wide range for developing first-brood larvæ. Maximum oviposition occurred from May 7 to 20, or from 15 to 30 days after full bloom on most varieties of apples.

No records were kept as to the length of the oviposition period for individuals. Oviposition was observed throughout the day, but chiefly in the evening and at night.

## FIRST GENERATION.

### FIRST BROOD OF EGGS.

*Incubation period.*—Practically all of the spring brood of moths that emerged were utilized for egg records and were placed in Riley cages, where they oviposited on apples suspended from strings. The apples were removed each morning and transferred to jelly glasses and kept under serial numbers. It was found necessary to cover the glasses with a fine piece of cloth in order to keep out hymenopterous egg parasites.

Table XII shows a complete record for 720 eggs deposited from April 26 to May 17.

Table XII.—*First-brood eggs. Incubation period of eggs laid in rearing cages.*

| No. of apple. | Number of eggs. | Date of deposition. | Red ring. | | Black spot. | | Hatched. | | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date. | Number of eggs. | |
| | | | | | | | | | *Days.* |
| 1 | 8 | Apr. 26 | May 1<br>May 2 | 5<br>3 | May 10<br>May 11 | 1<br>6 | May 13 | 8 | 17 |
| 2 | 18 | May 7 | May 9<br>May 10<br>May 15 | 4<br>7<br>1 | May 16<br>May 17 | 6<br>4 | May 17<br>May 18 | 1<br>15 | 10<br>11 |
| 3 | 20 | May 8 | May 10<br>May 11<br>May 12<br>May 13 | 1<br>2<br>9<br>7 | May 17<br>May 18 | 9<br>7 | May 18<br>May 19<br>May 20 | 3<br>8<br>4 | 10<br>11<br>12 |
| 4 | 22 | May 9 | May 12<br>May 13<br>May 14<br>May 16<br>May 17 | 6<br>8<br>1<br>1<br>2 | May 17<br>May 18<br>May 20 | 3<br>15<br>3 | May 20<br>May 21<br>May 22<br>May 23<br>May 24 | 6<br>2<br>6<br>1<br>2 | 11<br>12<br>13<br>14<br>15 |
| 5 | 2 | May 10 | May 13 | 2 | May 18 | 2 | May 20 | 2 | 10 |
| 6 | 3 | May 11 | May 14 | 2 | May 20 | 3 | May 22 | 3 | 11 |
| 7 | 218 | May 13 | May 13<br>May 14<br>May 15<br>May 16<br>May 17<br>May 18 | 18<br>4<br>71<br>53<br>25<br>6 | May 19<br>May 20<br>May 21<br>May 22<br>May 23<br>May 24 | 3<br>35<br>68<br>102<br>1<br>3 | May 22<br>May 23<br>May 24<br>May 25<br>May 26 | 10<br>44<br>30<br>42<br>66 | 9<br>10<br>11<br>12<br>13 |
| 8 | 186 | May 18 | May 19<br>May 20<br>May 21<br>May 24<br>May 26 | 5<br>1<br>17<br>34<br>7 | May 26<br>May 27<br>May 28 | 27<br>50<br>30 | May 28<br>May 29<br>May 30<br>June 1 | 45<br>26<br>30<br>14 | 10<br>11<br>12<br>14 |
| 9 | 16 | May 19 | May 21<br>May 24<br>May 26 | 3<br>6<br>6 | May 28<br>May 29 | 9<br>6 | June 1 | 14 | 12 |
| 10 | 52 | May 20 | May 24<br>May 25 | 11<br>20 | May 26<br>May 27<br>May 28 | 30<br>16<br>4 | May 28<br>May 30<br>June 1 | 25<br>15<br>10 | 8<br>10<br>11 |
| 11 | 26 | May 21 | May 22<br>May 23<br>May 24 | 3<br>2<br>4 | May 28<br>May 29<br>May 30 | 2<br>16<br>3 | May 30<br>June 1 | 18<br>4 | 9<br>10 |
| 12 | 1 | May 22 | .......... | ........ | May 30 | 1 | May 31 | 1 | 9 |

TABLE XII.—*First-brood eggs. Incubation period of eggs laid in rearing cages*—Contd.

| No. of apple. | Number of eggs. | Date of deposition. | Red ring. | | Black spot. | | Hatched. | | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date. | Number of eggs. | |
| | | | | | | | | | *Days.* |
| 13 | 132 | May 14 | May 14<br>May 15<br>May 16<br>May 17<br>May 18<br>May 19 | 12<br>13<br>29<br>16<br>36<br>12 | May 20<br>May 21<br>May 22<br>May 23 | 15<br>23<br>61<br>30 | May 23<br>May 24<br>May 25<br>May 26<br>May 27 | 22<br>39<br>30<br>16<br>12 | 9<br>10<br>11<br>12<br>13 |
| 14 | 69 | May 15 | May 16<br>May 17<br>May 18<br>May 20 | 10<br>30<br>11<br>6 | May 20<br>May 21<br>May 22<br>May 24<br>May 25 | 1<br>3<br>15<br>31<br>14 | May 25<br>May 26<br>May 27 | 25<br>23<br>13 | 10<br>11<br>12 |
| 15 | 24 | May 16 | May 17<br>May 18<br>May 19 | 1<br>14<br>2 | May 20<br>May 22<br>May 24<br>May 26 | 2<br>5<br>9<br>3 | May 24<br>May 26<br>May 27<br>May 29 | 2<br>2<br>3<br>22 | 8<br>10<br>11<br>13 |
| 16 | 100 | May 17 | May 18<br>May 19<br>May 20<br>May 22 | 23<br>43<br>16<br>8 | May 24<br>May 26<br>May 27 | 1<br>32<br>48 | May 27<br>May 28<br>May 29 | 11<br>55<br>10 | 10<br>11<br>12 |

In all 897 eggs were deposited and 720 hatched, or slightly over 80 per cent. The maximum length of the egg stage was 17 days, the minimum 8, and the average 12.4 days. (See Table XIII.) The red ring appeared after from 1 to 8 days but averaged from 2 to 5 days. The black spot appeared from 6 to 15 days after the eggs were deposited but usually appeared after 8 to 9 days.

An examination of Table XII shows that after the first lot of eggs had been deposited the length of the egg stage was fairly constant throughout the oviposition period of the spring moths. As has been observed by other writers, eggs which were deposited on the same day sometimes varied from one to three days in the length of the egg stage. This was due to differences in embryological development of the eggs within the body of the female.

TABLE XIII.—*Incubation period of first-brood eggs. Summary of Table XII.*

| Observations. | Days of incubation. |
|---|---|
| Average | 12.4 |
| Maximum | 17 |
| Minimum | 8 |

A summary of the incubation periods for the total number of eggs deposited by the spring-brood moths is shown in Table XIV.

TABLE XIV.—*Showing the variation in the length of the egg stage as recorded in Table XII.*

| Eggs. | Days. | Eggs. | Days. |
|---|---|---|---|
| 27 | 8 | 96 | 13 |
| 51 | 9 | 15 | 14 |
| 181 | 10 | 2 | 15 |
| 209 | 11 | 0 | 16 |
| 131 | 12 | 8 | 17 |

### FIRST BROOD OF LARVÆ.

As has been already stated, a number of the first-brood larvæ do not transform with the rest of the brood, but cocoon for the winter and hibernate with second-brood larvæ.

In rearing the codling-moth larvæ to obtain the time spent in feeding and the life cycle of the first generation, apples were used upon which several eggs had been deposited, in order to insure some of the larvæ living.

A number of the larvæ transformed within the half-dried apples and consequently only partial records can be given concerning them.

*Time of hatching.*—The first larvæ in the rearing cages appeared May 13 but these did not come from eggs deposited by the earliest moths on account of insufficient numbers of the latter.

It is very probable that the earliest larvæ appeared in the field from about April 20 to 25 if the time of emergence of the earliest moths, from March 30 to 31, is taken into consideration. As no effort was made to secure data as to when the latest larvæ hatched in the rearing cages this can not be given, but the latest hatching larvæ of the first brood probably appeared from about July 1 to 10, considering the time when the last moths emerged.

*Number of larvæ developing in one apple.*—In practically all of the rearing work to obtain a record of the time of feeding of the larvæ apples were used upon which a number of eggs had been deposited. In some instances as many as 20 eggs were laid on one apple but in no instance did a large number of larvæ mature. An examination of Table XV shows that usually one larva left the fruit, two larvæ left the apple in five instances, and three larvæ in one instance. In apples Nos. 11, 12, 13, 14, 15, and 16 a number of larvæ transformed, the number varying from 2 to 5. This seems to have been unusual according to the writings of other authors and was undoubtedly abnormal.

*Period of feeding of larvæ in fruit.*—In Table XV is recorded the feeding period of 46 larvæ which entered 16 apples, of which 27 left the apples, the rest remaining in the fruit; 31 larvæ transformed, 13 wintered, and 2 died. Of this number 25 transformed in the fruit, and 9 spun their cocoons, evidently intending to winter in the dried and shrunken apples.

TABLE XV.—*Larvæ of first brood. Feeding period of transforming and wintering larvæ; length of life cycle of first generation.*

| Number of apple. | Larvæ entered apple. |  | Larvæ left fruit. |  | Time spent in fruit. | Larvæ spun cocoons. |  | Larvæ pupated. |  | Adults emerged. |  | Length of pupal stage. | Total time spent in cocoons. | Theoretical length of life cycle. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Date. | Number of larvæ. | Date. | Number of larvæ. |  | Locality. | Number of larvæ. | Locality. | Number of larvæ. | Date. | Number of larvæ. |  |  |  |
|  |  |  |  |  | *Days.* |  |  |  |  |  |  | *Days.* | *Days.* |  |
| 1 | May 9 | 4 | June 11 | 1 | 33 | In apple. | .... | In apple. | .... | July 8 | 1 | ...... | ...... | 75.4 |
|  |  |  |  |  |  |  |  |  |  | July 10 | 1 | ...... | ...... | 77.4 |
|  |  |  |  |  |  |  |  |  |  | July 16 | 1 | ...... | ...... | 83.4 |
|  |  |  |  |  |  |  |  |  |  | July 20 | 1 | ...... | ...... | 87.4 |
| 2 | ...do.... | 2 | June 13 | 1 | 35 | ...do..... | .... | ...do..... | .... | July 8 | 1 | ...... | ...... | 75.4 |
|  |  |  | June 19 | 1 | 41 | ...do..... | .... | ...do..... | .... | July 20 | 1 | ...... | ...... | 87.4 |
| 3 | ...do..... | 2 | June 9 | 2 | 31 | ...do..... | .... | .......... | .... | (1) | .... | ...... | ...... | ...... |
| 4 | ...do..... | 1 | ...do..... | 1 | 31 | ...do..... | .... | In apple. | .... | July 22 | 1 | ...... | ...... | 89.4 |
| 5 | May 11 | 1 | June 22 | 1 | 42 | ...do..... | .... | .......... | .... | (1) | .... | ...... | ...... | ...... |
| 6 | May 13 | 2 | July 1 | 2 | 49 | ...do..... | .... | In apple. | .... | July 25 | 1 | ...... | ...... | 88.4 |
|  |  |  |  |  |  |  |  |  |  | (2) | .... | ...... | ...... | ...... |
| 7 | ...do.... | 2 | July 5 | 2 | 53 | ...do..... | .... | ...do..... | .... | July 25 | 1 | ...... | ...... | ...... |
|  |  |  |  |  |  |  |  |  |  | (2) | .... | ...... | ...... | ...... |
| 8 | May 18 | 5 | June 19 | 1 | 32 | ...do..... | .... | ...do..... | .... | July 8 | 1 | ...... | ...... | 64.4 |
|  |  |  |  |  |  |  |  |  |  | July 11 | 1 | ...... | ...... | 67.4 |
|  |  |  |  |  |  |  |  |  |  | July 19 | 1 | ...... | ...... | 75.4 |
|  |  |  |  |  |  |  |  |  |  | Aug. 3 | 1 | ...... | ...... | 90.4 |
|  |  |  |  |  |  |  |  |  |  | Aug. 14 | 1 | ...... | ...... | 101.4 |
| 9 | ...do..... | 4 | June 22 | 1 | 35 | ...do..... | .... | ...do..... | .... | July 16 | 1 | ...... | ...... | 74.4 |
|  |  |  |  |  |  |  |  |  |  | July 17 | 1 | ...... | ...... | 75.4 |
|  |  |  |  |  |  |  |  |  |  | July 19 | 2 | ...... | ...... | 77.4 |
| 10 | May 19 | 3 | June 9 | 2 | 29 | ...do..... | .... | ..do..... | .... | July 10 | 1 | ...... | ...... | 67.4 |
|  |  |  |  |  |  |  |  | ..do..... | .... | Aug. 3 | 1 | ...... | ...... | 91.4 |
|  |  |  |  |  |  |  |  | Aug. 11 | 1 | Died.... | .... | ...... | ...... | ...... |
| 11 | ...do..... | 5 | June 22 | 1 | 34 | ...do..... | .... | In apple. | .... | July 8 | 2 | ...... | ...... | 65.4 |
|  |  |  |  |  |  |  |  |  |  | July 10 | 1 | ...... | ...... | 67.4 |
|  |  |  |  |  |  |  |  |  |  | July 19 | 1 | ...... | ...... | 76.4 |
|  |  |  |  |  |  |  |  |  |  | July 11 | 1 | ...... | ...... | 68.4 |
| 12 | May 28 | 3 | June 30 | 1 | 33 | July 1 | 1 | July 1 | 1 | July 10 | 1 | 9 | 9 | 58.4 |
|  |  |  | July 3 | 1 | 36 | July 8 | 1 | .......... | .... | (3) | .... | ...... | ...... | ...... |
| 13 | May 29 | 3 | July 1 | 1 | 33 | July 8 | 1 | July 28 | 1 | Aug. 19 | 1 | 22 | 42 | 97.4 |
|  |  |  | July 2 | 1 | 34 | July 22 | 1 | .......... | .... | (3) | .... | ...... | ...... | ...... |
| 14 | June 1 | 3 | July 1 | 3 | 30 | July 2 | 2 | July 22 | 2 | Aug. 5 | 2 | 14 | 34 | 80.4 |
| 15 | ...do..... | 4 | June 30 | 1 | 29 | July 3 | 1 | .......... | .... | (3) | .... |  |  | ...... |
|  |  |  | July 1 | 1 | 30 | July 8 | 1 |  |  |  |  |  |  |  |
| 16 | ...do..... | 2 | July 2 | 2 | 31 | ..do..... | 1 | July 14 | 1 | July 28 | 1 | 14 | 20 | 72.4 |
|  |  |  |  |  |  | July 12 | 1 | July 22 | 1 | Aug. 15 | 1 | 24 | 34 | 90.4 |

(1) Wintered as larvæ. (2) One wintered as larva. (3) Two wintered as larvæ.

In Table XVI a summary is given of the time spent in feeding by the larvæ as shown in Table XV.

TABLE XVI.—*Feeding period of larvæ of first brood.*

| Observations. | Time spent in fruit. |
|---|---|
|  | *Days.* |
| Average.......... | 38.1 |
| Maximum.......... | 53 |
| Minimum.......... | 29 |

*Larval life in the cocoon.*—Individual records were kept upon the time of cocooning, time of pupation, and emergence of the moths on 141 larvæ. (See Tables XVIII and XIX.) Under this heading would be placed the post-larval stage or the period between the first spinning of the cocoon and the time of pupation. The variations in the length of larval life in the cocoon are given in Table XVII.

TABLE XVII.—*Larvæ of the first brood—Variations in the length of the larval life in the cocoon.*

| Number of larvæ. | Post-larval stage. | Number of larvæ. | Post-larval stage. | Number of larvæ. | Post-larval stage. | Number of larvæ. | Post-larval stage. |
|---|---|---|---|---|---|---|---|
| | *Days.* | | *Days.* | | *Days.* | | *Days.* |
| 3 | 2 | 1 | 10 | 2 | 21 | 1 | 31 |
| 2 | 3 | 3 | 11 | 3 | 22 | 1 | 36 |
| 12 | 4 | 3 | 13 | 3 | 23 | 1 | 39 |
| 11 | 5 | 3 | 16 | 2 | 25 | 1 | 39 |
| 38 | 6 | 4 | 17 | 1 | 26 | 1 | 40 |
| 7 | 7 | 2 | 18 | 2 | 27 | 1 | 41 |
| 4 | 8 | 1 | 19 | 4 | 29 | 1 | 50 |
| 12 | 9 | 1 | 20 | 3 | 30 | | |

From Table XVII it will be seen that the average larval life in the cocoon was 11.7 days, the maximum 50 and the minimum 2 days. The average post-larval stage is considerably longer than given by either Mr. Jenne[1] in Arkansas in 1908 or by Mr. Hammar[2] in Pennsylvania in 1909, in their studies of the codling moth. The former obtained an average of 7.2 days, a maximum of 19 days, and a minimum of 3 days, while the latter obtained an average of 7.09 days, a maximum of 19 days, and a minimum of 3 days.

### FIRST BROOD OF PUPÆ.

*Time of pupation.*—The first pupæ observed in the field were collected from under the bands on June 6 and from then on weekly to August 15. The first pupa observed in the cages was on June 25 and the last on August 20. Pupæ appeared in maximum numbers in the cages throughout the month of July. Considering the date of the emergence of the last moth on September 22 and subtracting the average length of the pupal stage, the date of the last larva pupating must have been about September 3.

*Length of the first-brood pupal stage.*—The larvæ upon which the pupal records are based were collected from banded trees in 1910. One collection was made June 10 of 46 larvæ and one June 20 of 95 larvæ, making a total of 141. In the first collections 11 larvæ were males and 35 females and in the second 27 individuals were males and 68 females. The sex of the larvæ was determined in the same manner as was that of the overwintering larvæ. (See p. 122.)

Table XVIII shows a detailed record of the 38 male larvæ which had an average pupal stage of 19.5 days; Table XIX shows a detailed record of the 102 female larvæ which had an average pupal stage of 18.8 days. From records of the overwintering larvæ and similar records for 1911 it was apparent that female larvæ required a longer pupal period. The above record seems to contradict the other records as 68 female larvæ, or 66 per cent of the total number of females, were collected on June 30, the second collection, while 27 male larvæ, or 71 per cent of the total number of males, were taken on the second collection. It is evident therefore that a larger percentage of the total number of males was influenced by a higher mean temperature (on account of later collection in June) than females, which would naturally lead one to expect a shorter average pupal stage for the males in comparison with that of the females. Possibly a few individuals with a long pupal stage in the male series of 38 individuals caused a greater influence on the average length of the stage than the same number of individuals in the female series of 103 larvæ would do.

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[1] U. S. Dept. Agr., Bur. Ent., Bul. 80, Part I.

[2] U. S. Dept. Agr., Bur. Ent., Bul. 80, Part VI.

The average length of the pupal stage of all the larvæ was 19.04 days, the maximum 55 and the minimum 11 days. (See Table XX.) A summary of Tables XVIII and XIX is given in Table XX, showing the variations observed in the length of the stages during the entire period when pupæ were found.

Table XVIII.—*Pupæ of the first brood—Length of the pupal and cocoon periods of 38 male larvæ collected in 1910 on banded trees.*

| No. | Date— | | | Length of pupal stage. | Length of cocoon stage. | No. | Date— | | | Length of pupal stage. | Length of cocoon stage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spun cocoon. | Pupated. | Emerged. | | | | Spun cocoon. | Pupated. | Emerged. | | |
| | | | | *Days.* | *Days.* | | | | | *Days.* | *Days.* |
| 1 | June 21 | June 25 | July 11 | 16 | 20 | 20 | July 1 | July 7 | July 22 | 15 | 21 |
| 2 | ...do..... | June 27 | July 14 | 17 | 23 | 21 | ...do..... | ...do..... | July 20 | 13 | 19 |
| 3 | ...do..... | June 25 | July 17 | 22 | 26 | 22 | .......... | Aug. 9 | Aug. 28 | 19 | ...... |
| 4 | ...do..... | June 27 | ...do..... | 20 | 26 | 23 | July 1 | July 7 | July 23 | 16 | 22 |
| 5 | ...do..... | ...do..... | ...do..... | 20 | 26 | 24 | ...do..... | Aug. 1 | Sept. 2 | 32 | 63 |
| 6 | June 22 | July 1 | July 19 | 18 | 27 | 25 | ...do..... | July 5 | July 20 | 15 | 19 |
| 7 | ...do..... | July 9 | July 27 | 18 | 25 | 26 | ...do..... | July 23 | Aug. 16 | 24 | 46 |
| 8 | ...do..... | July 19 | Aug. 9 | 21 | 48 | 27 | ...do..... | Aug. 10 | Sept. 4 | 25 | 65 |
| 9 | June 24 | June 30 | July 17 | 17 | 23 | 28 | ...do..... | July 27 | Aug. 15 | 19 | 55 |
| 10 | ...do..... | June 20 | Aug. 10 | 21 | 47 | 29 | ...do..... | July 7 | July 21 | 14 | 20 |
| 11 | ...do..... | July 12 | Aug. 1 | 20 | 38 | 30 | ...do..... | July 28 | Aug. 25 | 28 | 55 |
| 12 | July 1 | July 30 | Aug. 24 | 25 | 54 | 31 | ...do..... | July 7 | July 20 | 13 | 19 |
| 13 | ...do..... | July 24 | Aug. 13 | 20 | 43 | 32 | July 2 | July 9 | July 27 | 18 | 25 |
| 14 | ...do..... | ...do..... | Aug. 16 | 23 | 46 | 33 | ...do..... | July 8 | July 24 | 16 | 22 |
| 15 | ...do..... | July 19 | Aug. 10 | 22 | 40 | 34 | ...do..... | July 7 | ...do..... | 17 | 22 |
| 16 | ...do..... | July 5 | July 20 | 15 | 19 | 35 | ...do..... | Aug. 1 | Sept. 1 | 31 | 61 |
| 17 | ...do..... | July 7 | July 23 | 16 | 22 | 36 | July 4 | July 14 | Aug. 3 | 20 | 30 |
| 18 | ...do..... | ...do..... | July 27 | 20 | 26 | 37 | July 11 | July 15 | ...do..... | 19 | 23 |
| 19 | .......... | ...do..... | July 24 | 17 | ...... | 38 | July 12 | July 16 | Aug. 7 | 22 | 26 |

TABLE XIX.—*Pupæ of the first brood. Length of the pupal and cocoon periods of 103 female larvæ collected on banded trees, 1910.*

| No. | Date— | | | Length of pupal stage. | Length of cocoon stage. | No. | Date— | | | Length of pupal stage. | Length of cocoon stage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spun cocoon. | Pupated. | Emerged. | *Days.* | *Days.* | | Spun cocoon. | Pupated. | Emerged. | *Days.* | *Days.* |
| 1 | June 21 | June 25 | July 13 | 18 | 22 | 53 | July 1 | July 7 | July 21 | 14 | 20 |
| 2 | ...do..... | June 27 | July 15 | 18 | 24 | 54 | ...do..... | July 9 | July 23 | 14 | 22 |
| 3 | ...do..... | ...do..... | July 17 | 20 | 26 | 55 | ...do..... | July 7 | July 24 | 17 | 23 |
| 4 | ...do..... | June 26 | July 15 | 19 | 24 | 56 | ...do..... | Aug. 20 | Sept. 18 | 29 | 79 |
| 5 | .......... | June 25 | July 17 | 22 | ...... | 57 | ...do..... | July 7 | July 23 | 16 | 22 |
| 6 | .......... | June 30 | Aug. 24 | 55 | ...... | 58 | ...do..... | ...do..... | July 21 | 14 | 20 |
| 7 | June 21 | June 25 | July 14 | 19 | 23 | 59 | ...do..... | ...do..... | July 20 | 13 | 19 |
| 8 | ...do..... | June 30 | July 18 | 18 | 27 | 60 | ...do..... | July 10 | July 27 | 17 | 26 |
| 9 | ...do..... | June 27 | July 17 | 20 | 26 | 61 | ...do..... | July 8 | July 24 | 16 | 23 |
| 10 | ...do..... | ...do..... | July 15 | 18 | 24 | 62 | ...do..... | July 7 | July 20 | 13 | 19 |
| 11 | ...do..... | ...do..... | July 17 | 20 | 26 | 63 | ...do..... | July 14 | Aug. 1 | 18 | 31 |
| 12 | ...do..... | July 11 | July 27 | 16 | 36 | 64 | ...do..... | July 18 | Aug. 7 | 20 | 37 |
| 13 | ...do..... | June 27 | July 17 | 20 | 26 | 65 | ...do..... | July 7 | July 21 | 14 | 20 |
| 14 | ...do..... | June 25 | July 13 | 18 | 22 | 66 | ...do..... | July 17 | Aug. 7 | 21 | 37 |
| 15 | ...do..... | June 27 | July 17 | 20 | 26 | 67 | ...do..... | July 7 | July 23 | 16 | 22 |
| 16 | ...do..... | Aug. 1 | Aug. 31 | 30 | 71 | 68 | ...do..... | ...do..... | July 21 | 14 | 20 |
| 17 | ...do..... | June 30 | July 18 | 18 | 27 | 69 | ...do..... | July 10 | July 28 | 18 | 27 |
| 18 | ...do..... | ...do..... | ...do..... | 18 | 27 | 70 | ...do..... | July 17 | Aug. 6 | 20 | 36 |
| 19 | ...do..... | July 21 | Aug. 15 | 25 | 55 | 71 | ...do..... | July 12 | July 31 | 19 | 30 |
| 20 | ...do..... | June 30 | July 17 | 17 | 26 | 72 | ...do..... | July 23 | Aug. 19 | 27 | 49 |
| 21 | ...do..... | June 27 | July 15 | 18 | 24 | 73 | ...do..... | ...do..... | Aug. 16 | 24 | 46 |
| 22 | ...do..... | ...do..... | July 17 | 20 | 26 | 74 | ...do..... | July 7 | July 24 | 17 | 23 |
| 23 | ...do..... | July 2 | July 20 | 18 | 29 | 75 | ...do..... | July 22 | Aug. 15 | 24 | 45 |
| 24 | ...do..... | June 30 | July 17 | 17 | 26 | 76 | ...do..... | July 3 | July 22 | 19 | 21 |
| 25 | June 22 | ...do..... | July 18 | 18 | 26 | 77 | ...do..... | July 14 | Aug. 3 | 20 | 33 |
| 26 | .......... | June 29 | ...do..... | 19 | ...... | 78 | ...do..... | July 3 | July 20 | 17 | 19 |
| 27 | June 22 | June 25 | July 13 | 18 | 21 | 79 | ...do..... | July 10 | July 21 | 11 | 20 |
| 28 | ...do..... | July 1 | July 20 | 19 | 28 | 80 | July 2 | July 6 | ...do..... | 15 | 19 |
| 29 | ...do..... | July 3 | ...do..... | 17 | 28 | 81 | ...do..... | July 9 | July 25 | 16 | 23 |
| 30 | ...do..... | June 30 | ...do..... | 20 | 28 | 82 | ...do..... | July 25 | Aug. 18 | 24 | 47 |
| 31 | ...do..... | June 27 | July 17 | 20 | 25 | 83 | ...do..... | July 7 | July 21 | 14 | 19 |
| 32 | ...do..... | ...do..... | ...do..... | 20 | 25 | 84 | ...do..... | ...do..... | July 20 | 13 | 18 |
| 33 | June 23 | ...do..... | ...do..... | 20 | 24 | 85 | ...do..... | ...do..... | July 21 | 14 | 19 |
| 34 | June 24 | July 15 | Aug. 3 | 19 | 40 | 86 | ...do..... | July 6 | ...do..... | 15 | 19 |
| 35 | ...do..... | July 1 | July 18 | 17 | 24 | 87 | ...do..... | July 7 | July 20 | 13 | 18 |
| 36 | July 1 | July 7 | July 21 | 14 | 20 | 88 | ...do..... | Aug. 1 | Sept. 4 | 34 | 64 |
| 37 | ...do..... | ...do..... | ...do..... | 14 | 20 | 89 | ...do..... | July 11 | July 28 | 17 | 26 |
| 38 | ...do..... | July 26 | Aug. 21 | 26 | 51 | 90 | ...do..... | July 18 | Aug. 9 | 22 | 38 |
| 39 | ...do..... | July 8 | July 24 | 16 | 23 | 91 | .......... | July 26 | Aug. 18 | 23 | .... |
| 40 | ...do..... | July 30 | Aug. 24 | 25 | 54 | 92 | July 2 | July 7 | July 21 | 14 | 19 |
| 41 | ...do..... | July 4 | July 20 | 16 | 19 | 93 | ...do..... | Aug. 10 | Sept. 10 | 31 | 70 |
| 42 | ...do..... | July 8 | July 23 | 15 | 22 | 94 | ...do..... | July 8 | July 24 | 16 | 22 |
| 43 | ...do..... | ...do..... | July 25 | 17 | 24 | 95 | ...do..... | July 31 | Aug. 29 | 29 | 58 |
| 44 | .......... | July 18 | Aug. 7 | 20 | ...... | 96 | ...do..... | July 8 | July 24 | 16 | 22 |
| 45 | July 1 | ...do..... | Aug. 6 | 19 | 36 | 97 | ...do..... | July 7 | July 21 | 14 | 19 |
| 46 | ...do..... | July 7 | July 20 | 13 | 19 | 98 | ...do..... | July 4 | July 20 | 16 | 18 |
| 47 | ...do..... | July 9 | July 28 | 19 | 27 | 99 | .......... | July 7 | July 24 | 17 | .... |
| 48 | ...do..... | July 7 | July 21 | 14 | 20 | 100 | July 2 | ...do..... | July 23 | 16 | 21 |
| 49 | ...do..... | ...do..... | ...do..... | 14 | 20 | 101 | July 3 | July 22 | Aug. 14 | 23 | 42 |
| 50 | ...do..... | July 14 | Aug. 1 | 18 | 31 | 102 | ...do..... | July 8 | July 24 | 16 | 21 |
| 51 | ...do..... | July 10 | July 27 | 17 | 26 | 103 | July 7 | Aug. 4 | Sept. 2 | 29 | 57 |
| 52 | ...do..... | July 8 | July 24 | 16 | 23 | | | | | | |

TABLE XX.—*Pupæ of the first brood; length of pupal period. Summary of Tables XVIII and XIX.*

| Observations. | Pupal period. |
|---|---|
| | *Days.* |
| Average.......... | 19.04 |
| Maximum........ | 55 |
| Minimum........ | 11 |

TABLE XXI.—*Pupæ of the first brood; variation in length of pupal stage. Summary of Tables XVIII and XIX.*

| Number of pupæ. | Pupal stage. | Number of pupæ. | Pupal stage. | Number of pupæ. | Pupal stage. | Number of pupæ. | Pupal stage. |
|---|---|---|---|---|---|---|---|
| | *Days.* | | *Days.* | | *Days.* | | *Days.* |
| 1 | 11 | 3 | 23 | 0 | 35 | 0 | 47 |
| 0 | 12 | 4 | 24 | 0 | 36 | 0 | 48 |
| 7 | 13 | 4 | 25 | 0 | 37 | 0 | 49 |
| 14 | 14 | 1 | 26 | 0 | 38 | 0 | 50 |
| 6 | 15 | 1 | 27 | 0 | 39 | 0 | 51 |
| 17 | 16 | 1 | 28 | 0 | 40 | 0 | 52 |
| 16 | 17 | 3 | 29 | 0 | 41 | 0 | 53 |
| 17 | 18 | 1 | 30 | 0 | 42 | 0 | 54 |
| 12 | 19 | 2 | 31 | 0 | 43 | 0 | 55 |
| 20 | 20 | 1 | 32 | 0 | 44 | | |
| 3 | 21 | 0 | 33 | 0 | 45 | | |
| 5 | 22 | 1 | 34 | 0 | 46 | | |

### FIRST BROOD OF MOTHS.

*Time of emergence.*—On July 8 the earliest first-brood moths appeared from band material collected June 7, while the last moth of the spring brood emerged June 9. The gap between the last spring moths and the earliest first-brood moths was therefore about one month.

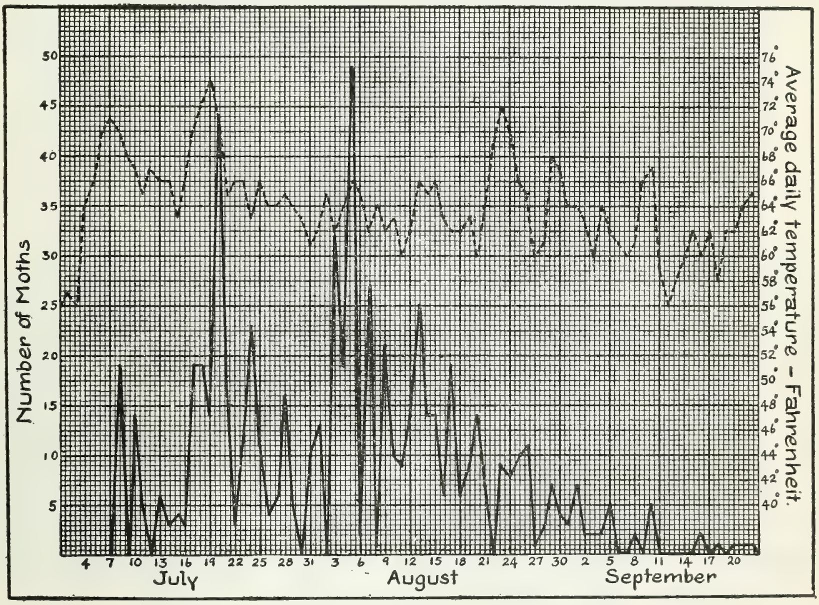

FIG. 30.—Diagram showing emergence of first-brood moths for 1910. (Original.)

As shown in figure 30 and Table XXII moths emerged in large numbers and in small numbers intermittently until September 22. No absolute maximum could be determined, but the majority of the moths emerged during a period embracing the latter half of July and the first half of August. As shown in figure 30, the daily mean temperature seems to have influenced emergence to some extent, especially during the early part. After August 18, when most of the moths had already emerged, no conclusions could be drawn regarding the influence of temperature conditions.

The emergence curves of both spring and first-brood moths, as recorded at San Jose, are very much at variance with those of Mr. Hammar[1] at North East, Pa., who obtained more gradual maximums and minimums and not such sudden rises and falls as are recorded in this paper. The warmer nights in the Eastern States undoubtedly bring about this set of conditions.

TABLE XXII.—*Emergence of moths of the first brood from material collected from banded trees.*

| Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. |
|---|---|---|---|---|---|---|---|
| July 8 | 19 | July 26 | 4 | Aug. 13 | 25 | Aug. 30 | 4 |
| July 10 | 14 | July 27 | 6 | Aug. 14 | 14 | Aug. 31 | 3 |
| July 11 | 5 | July 28 | 16 | Aug. 15 | 14 | Sept. 1 | 7 |
| July 13 | 6 | July 29 | 5 | Aug. 16 | 6 | Sept. 2 | 2 |
| July 14 | 3 | July 31 | 10 | Aug. 17 | 19 | Sept. 3 | 2 |
| July 15 | 4 | Aug. 1 | 13 | Aug. 18 | 6 | Sept. 4 | 2 |
| July 16 | 3 | Aug. 3 | 32 | Aug. 19 | 8 | Sept. 5 | 5 |
| July 17 | 19 | Aug. 4 | 19 | Aug. 20 | 14 | Sept. 8 | 2 |
| July 18 | 19 | Aug. 5 | 49 | Aug. 21 | 7 | Sept. 10 | 5 |
| July 19 | 14 | Aug. 6 | 2 | Aug. 23 | 9 | Sept. 16 | 2 |
| July 20 | 44 | Aug. 7 | 27 | Aug. 24 | 8 | Sept. 18 | 1 |
| July 21 | 18 | Aug. 8 | 1 | Aug. 25 | 10 | Sept. 20 | 1 |
| July 22 | 3 | Aug. 9 | 22 | Aug. 26 | 11 | Sept. 21 | 1 |
| July 23 | 12 | Aug. 10 | 10 | Aug. 27 | 1 | Sept. 22 | 1 |
| July 24 | 23 | Aug. 11 | 9 | Aug. 28 | 3 | | |
| July 25 | 11 | Aug. 12 | 14 | Aug. 29 | 7 | | |

*Oviposition period.*—No individual records for oviposition were kept except that 10 or 12 separate pairs were confined in mica chimneys to find out the total number of eggs a single moth would deposit. Unfortunately these notes were lost and also the data on the length of oviposition. It will be seen later from data on the length of the egg stage that eggs were obtained July 9, one day after the first moths emerged. This appears to be unusual and in all probability the first moths emerged before July 8, but were overlooked in the jars. General observations on the length of oviposition, while securing eggs in the cages, made it evident that some moths deposited eggs for from 7 days up to 2 weeks.

### LIFE CYCLE OF FIRST GENERATION.

As will be seen in Table XV, a number of larvæ were reared in apples and records kept until the moths emerged. This with the exception of the length of the egg stage and an addition of 3 days (time before oviposition) would give the life cycle, which is properly from egg to egg. The average length of the egg stage of the first generation being 12.4 days plus 3 days makes 15.4 days, to be added to each period where the larva was reared to a moth.

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[1] U. S. Dept. Agr., Bur. Ent., Bul. 80, Part VI.

A summary of Table XV shows the following data:

TABLE XXIII.—*Summary of Table XV showing the theoretical life cycle of the first generation.*

| Number of individuals. | Length of life cycle. | Number of individuals. | Length of life cycle. | Number of individuals. | Length of life cycle. | Number of individuals. | Length of life cycle. |
|---|---|---|---|---|---|---|---|
| | *Days.* | | *Days.* | | *Days.* | | *Days.* |
| 1........ | 72.4 | 1........ | 89.4 | 1........ | 74.4 | 1........ | 76.4 |
| 2........ | 90.4 | 2........ | 88.4 | 3........ | 77.4 | 1........ | 68.4 |
| 1........ | 58.4 | 4........ | 75.4 | 3........ | 67.4 | 1........ | 64.4 |
| 1........ | 97.4 | 1........ | 83.4 | 1........ | 91.4 | 1........ | 101.4 |
| 2........ | 80.4 | 2........ | 87.4 | 2........ | 65.4 | | |

A summary of Table XXIII shows the average life cycle to be 78.62 days, the maximum 101.4 days, and the minimum 58.4 days. The average length of the egg stage, 12.4 days, added to the average feeding period of the larvæ, 38.1 days, added to 11.7 days, the average postlarval stage, added to 19.4 days, the average pupal stage, added to 3 days' time before oviposition, makes a total of 84.24 days, which is about 6 days more than was obtained by actual rearing records.

## SECOND GENERATION.

### SECOND BROOD OF EGGS.

*Incubation period.*—The same methods were used for obtaining eggs of the second generation as were practiced on the first generation, viz, placing moths in Riley cages in which apples were suspended by strings. Nearly all of the moths were utilized for this work throughout the emergence period, thus giving practically the true period of oviposition that would naturally obtain in the field. In this manner eggs were obtained from July 9 up to September 25, inclusive, a period of 78 days. Eggs were obtained in the cages the day after the emergence of the earliest first-brood moths, and three days after the last first-brood moth emerged. Moths emerged in such small numbers during the month of September that proper mating was hindered and consequently few eggs were deposited after the last moth emerged.

A record was kept of the second-brood eggs, as with the first-brood eggs, showing the length before the red ring appeared and before the black spot appeared, both of which indicate distinct periods, so that when eggs are obtained in the field they can be classed according to their age with some degree of accuracy.

In the cages eggs were obtained practically every day from July 9 to September 25, and in all a total of 1,861 eggs were kept under observation, 1,748 of which hatched, or a total of 93 per cent. A complete record of the incubation periods of all the eggs is shown in Table XXIV.

TABLE XXIV.—*Second-brood eggs. Incubation period of eggs laid in rearing cages.*

| No. of apple. | Number of eggs. | Date of deposition. | Red ring. | | Black spot. | | Hatched. | | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date. | Number of eggs. | |
| | | | | | | | | | *Days.* |
| 1 | 2 | July 9 | July 12 | 2 | July 18 | 2 | July 19 | 2 | 10 |
| 2 | 4 | ...do.... | ...do.... | 4 | ...do.... | 4 | ...do.... | 4 | 10 |
| 3 | 7 | July 10 | ...do.... | 7 | ...do.... | 7 | ...do.... | 7 | 9 |
| 4 | 2 | July 11 | July 13 | 2 | ..do....<br>July 19 | 1<br>1 | July 20 | 2 | 9 |
| 5 | 4 | ...do.... | ...do.... | 4 | ...do.... | 4 | ...do.... | 4 | 9 |
| 6 | 1 | ...do.... | ...do.... | 1 | ...do.... | 1 | July 21 | 1 | 10 |
| 7 | 1 | July 12 | ...do.... | 1 | ...do.... | 1 | July 20 | 1 | 8 |
| 8 | 4 | ...do.... | July 14 | 3 | ...do.... | 3 | ..do....<br>July 21 | 2<br>1 | 8<br>9 |
| 9 | 6 | ...do.... | ...do.... | 6 | ...do.... | 6 | July 20<br>July 21 | 3<br>3 | 8<br>9 |
| 10 | 10 | ...do.... | ...do.... | 10 | ...do.... | 8 | July 20<br>July 21 | 3<br>5 | 8<br>9 |
| 11 | 2 | ...do.... | ...do.... | 2 | ...do.... | 2 | July 20 | 2 | 8 |
| 12 | 6 | July 13 | July 15 | 6 | July 20 | 6 | July 21 | 6 | 8 |
| 13 | 2 | ...do.... | ...do.... | 1 | ...do.... | 2 | ...do.... | 2 | 8 |
| 14 | 1 | ...do.... | ...do.... | 1 | ...do.... | 1 | ...do.... | 1 | 8 |
| 15 | 3 | ...do.... | ...do.... | 3 | ...do.... | 3 | ...do.... | 3 | 8 |
| 16 | 5 | ...do.... | ...do.... | 5 | ...do.... | 5 | ...do.... | 5 | 8 |
| 17 | 2 | July 14 | ...do.... | 2 | ...do.... | 2 | ...do.... | 2 | 7 |
| 18 | 3 | ...do.... | July 16 | 2 | July 21 | 3 | ...do.... | 2 | 7 |
| 19 | 3 | ...do.... | ...do.... | 3 | July 20 | 1 | ...do.... | 3 | 7 |
| 20 | 3 | ...do.... | ...do.... | 2 | ...do.... | 1 | ...do.... | 3 | 7 |
| 21 | 2 | ...do.... | ...do.... | 2 | July 21 | 2 | ...do.... | 2 | 7 |
| 22 | 2 | ...do.... | ...do.... | 2 | ...do.... | 2 | ...do.... | 2 | 7 |
| 23 | 1 | ...do.... | ...do.... | 1 | ...do.... | 1 | ...do.... | 1 | 7 |
| 24 | 14 | ...do.... | ...do.... | 14 | ...do.... | 14 | ...do.... | 14 | 7 |
| 25 | 1 | July 15 | July 17 | 1 | ...do.... | 1 | July 23 | 1 | 8 |
| 26 | 1 | July 16 | July 18 | 1 | July 22 | 1 | ...do.... | 1 | 7 |
| 27 | 3 | July 17 | ..do....<br>July 19 | 1<br>2 | July 23 | 3 | July 24<br>July 26 | 1<br>2 | 7<br>9 |
| 28 | 5 | ...do.... | ...do.... | 5 | ...do.... | 5 | July 24<br>July 26 | 3<br>2 | 7<br>9 |
| 29 | 3 | July 19 | July 20 | 2 | July 24<br>July 25<br>July 26 | 1<br>1<br>1 | July 27 | 3 | 8 |
| 30 | 5 | July 21 | July 22<br>July 23 | 1<br>3 | July 28<br>July 29 | 2<br>3 | July 29<br>July 30<br>July 31 | 1<br>3<br>1 | 8<br>9<br>10 |
| 31 | 7 | ...do.... | ..do....<br>July 24 | 5<br>2 | ..do.... | 7 | ..do....<br>July 31 | 3<br>4 | 9<br>10 |
| 32 | 11 | ...do.... | July 23<br>July 24 | 8<br>3 | ..do.... | 11 | ...do.... | 11 | 10 |
| 33 | 6 | July 22 | ...do.... | 6 | July 31 | 6 | Aug. 1 | 6 | 10 |
| 34 | 1 | ...do.... | ...do.... | 1 | ...do.... | 1 | ...do.... | 1 | 10 |
| 35 | 1 | ...do.... | ...do.... | 1 | ...do.... | 1 | ...do.... | 1 | 10 |
| 36 | 3 | ...do.... | ...do.... | 3 | ...do.... | 3 | ..do....<br>Aug. 2 | 2<br>1 | 10<br>11 |
| 37 | 10 | ...do.... | ...do.... | 10 | ...do.... | 10 | Aug. 1<br>Aug. 2 | 6<br>4 | 10<br>11 |
| 38 | 2 | ...do.... | ...do.... | 2 | ...do.... | 1 | Aug. 1 | 2 | 10 |
| 39 | 15 | July 23 | July 25 | 13 | Aug. 1 | 15 | Aug. 3 | 13 | 11 |
| 40 | 8 | ...do.... | ...do.... | 8 | ...do.... | 8 | ...do.... | 8 | 11 |
| 41 | 8 | ...do.... | ...do.... | 8 | ...do.... | 8 | ...do.... | 8 | 11 |
| 42 | 3 | ...do.... | ...do.... | 2 | ...do.... | 2 | ...do.... | 3 | 11 |
| 43 | 29 | July 24 | July 26<br>July 27 | 24<br>2 | Aug. 2<br>Aug. 3 | 16<br>10 | Aug. 4 | 26 | 11 |
| 44 | 14 | ...do.... | July 26<br>Aug. 1 | 13<br>1 | Aug. 2<br>Aug. 3 | 12<br>2 | ...do....<br>Aug. 5 | 12<br>2 | 11<br>12 |
| 45 | 14 | ...do.... | July 26<br>July 28 | 8<br>6 | Aug. 2<br>Aug. 3 | 2<br>1 | Aug. 4<br>Aug. 5 | 1<br>2 | 11<br>12 |
| 46 | 21 | ...do.... | July 26<br>July 28 | 17<br>4 | Aug. 2<br>Aug. 3<br>Aug. 4 | 6<br>5<br>2 | Aug. 4 | 9 | 11 |
| 47 | 17 | July 25 | ...do.... | 13 | Aug. 3<br>Aug. 4 | 5<br>12 | Aug. 5<br>Aug. 6 | 8<br>7 | 11<br>12 |
| 48 | 8 | ...do.... | ...do.... | 6 | Aug. 3<br>Aug. 4 | 2<br>6 | Aug. 5<br>Aug. 6 | 2<br>2 | 11<br>12 |

**Table XXIV.**—*Second-brood eggs. Incubation period of eggs laid in rearing cages*—Continued.

| Number of apple. | Number of eggs. | Date of deposition. | Red ring. |  | Black spot. |  | Hatched. |  | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date. | Number of eggs. |  |
|  |  |  |  |  |  |  |  |  | *Days.* |
| 49 | 23 | July 25 | July 28 | 15 | Aug. 3<br>Aug. 4 | 14<br>9 | Aug. 5<br>Aug. 6 | 11<br>9 | 11<br>12 |
| 50 | 10 | July 26 | ...do.... | 9 | Aug. 3<br>Aug. 4 | 3<br>7 | Aug. 5<br>Aug. 6 | 2<br>6 | 10<br>11 |
| 51 | 31 | ...do.... | ...do.... | 28 | Aug. 3<br>Aug. 4 | 18<br>13 | Aug. 5<br>Aug. 6<br>Aug. 7 | 9<br>13<br>1 | 10<br>11<br>12 |
| 52 | 16 | ...do.... | ..do....<br>July 29 | 6<br>8 | Aug. 4<br>Aug. 5 | 7<br>4 | Aug. 5<br>Aug. 7 | 5<br>11 | 10<br>11 |
| 53 | 11 | ...do.... | July 28<br>July 29 | 4<br>6 | Aug. 4<br>Aug. 5 | 5<br>1 | Aug. 5<br>Aug. 7 | 5<br>6 | 10<br>12 |
| 54 | 3 | ...do.... | July 28 | 3 | Aug. 4<br>Aug. 5 | 1<br>2 | Aug. 6<br>Aug. 7 | 1<br>2 | 11<br>12 |
| 55 | 4 | ...do.... | ...do.... | 2 | ...do.... | 3 | ...do.... | 3 | 12 |
| 56 | 10 | ...do.... | ...do.... | 6 | Aug. 4<br>Aug. 5 | 5<br>2 | Aug. 5<br>Aug. 6<br>Aug. 7 | 3<br>3<br>4 | 10<br>11<br>12 |
| 57 | 11 | July 27 | July 29 | 7 | ..do....<br>Aug. 6 | 7<br>3 | ..do....<br>Aug. 8<br>Aug. 9 | 4<br>3<br>3 | 11<br>12<br>13 |
| 58 | 2 | ...do.... | Aug. 5 | 1 | .......... | ........ | .......... | ........ | ........ |
| 59 | 4 | ...do.... | July 28 | 3 | Aug. 5<br>Aug. 7 | 3<br>1 | Aug. 7<br>Aug. 8<br>Aug. 10 | 2<br>1<br>1 | 11<br>12<br>14 |
| 60 | 7 | ...do.... | ...do.... | 6 | Aug. 5<br>Aug. 6 | 4<br>2 | Aug. 7 | 6 | 11 |
| 61 | 3 | July 28 | Aug. 1 | 1 | Aug. 7 | 3 | Aug. 9 | 3 | 12 |
| 62 | 9 | ...do.... | ...do.... | 4 | Aug. 5 | 1 | .......... | ........ | ........ |
| 63 | 1 | ...do.... | ...do.... | 1 | .......... | ........ | .......... | ........ | ........ |
| 64 | 2 | ...do.... | July 28<br>Aug. 1 | 1<br>1 | Aug. 7 | 2 | Aug. 9 | 2 | 12 |
| 65 | 2 | July 29 | ...do.... | 2 | ...do.... | 2 | ...do.... | 2 | 11 |
| 66 | 14 | July 30 | ..do....<br>Aug. 2<br>Aug. 5 | 2<br>6<br>4 | Aug. 8<br>Aug. 9<br>Aug. 10 | 5<br>8<br>1 | Aug. 10<br>Aug. 11 | 12<br>1 | 11<br>12 |
| 67 | 6 | ...do.... | Aug. 1<br>Aug. 2 | 5<br>1 | Aug. 8<br>Aug. 9 | 2<br>4 | Aug. 10 | 6 | 11 |
| 68 | 7 | ...do.... | ..do....<br>Aug. 3<br>Aug. 4 | 3<br>1<br>3 | Aug. 8 | 7 | ...do.... | 7 | 11 |
| 69 | 9 | July 31 | Aug. 2<br>Aug. 3 | 3<br>6 | Aug. 9 | 9 | Aug. 11<br>Aug. 12 | 8<br>1 | 11<br>12 |
| 70 | 7 | ...do.... | Aug. 2 | 6 | ...do.... | 7 | Aug. 11 | 7 | 11 |
| 71 | 20 | ...do.... | ..do....<br>Aug. 3 | 8<br>12 | ..do.... | 20 | ..do....<br>Aug. 12 | 19<br>1 | 11<br>12 |
| 72 | 6 | Aug. 1 | ...do.... | 5 | Aug. 10 | 6 | Aug. 11<br>Aug. 12 | 1<br>5 | 10<br>11 |
| 73 | 4 | ...do.... | ..do....<br>Aug. 4 | 2<br>1 | ..do.... | 3 | ...do.... | 1 | 11 |
| 74 | 4 | Aug. 2 | ..do....<br>Aug. 5 | 1<br>3 | ..........<br>.......... | ........<br>........ | ..........<br>.......... | ........<br>........ | ........<br>........ |
| 75 | 16 | ...do.... | Aug. 4<br>Aug. 5 | 12<br>4 | Aug. 11 | 16 | Aug. 13 | 16 | 11 |
| 77 | 17 | ...do.... | Aug. 4<br>Aug. 5 | 6<br>8 | ..do.... | 17 | Aug. 14 | 17 | 11 |
| 78 | 18 | Aug. 3 | ..do....<br>Aug. 6 | 16<br>2 | Aug. 12<br>...do.... | 12<br>6 | ...do....<br>Aug. 15 | 14<br>4 | 11<br>12 |
| 79 | 11 | ...do.... | Aug. 5<br>Aug. 6 | 4<br>1 | ...do....<br>Aug. 13 | 8<br>3 | Aug 14<br>Aug. 15 | 7<br>4 | 11<br>12 |
| 80 | 9 | ...do.... | Aug. 5 | 9 | Aug. 12<br>Aug. 13 | 3<br>6 | Aug. 14<br>Aug. 15 | 4<br>4 | 11<br>12 |
| 81 | 4 | Aug. 4 | Aug. 6 | 4 | Aug. 14 | 4 | ...do.... | 4 | 11 |
| 82 | 3 | ...do..... | ...do..... | 3 | Aug. 13 | 3 | ...do..... | 3 | 11 |
| 83 | 4 | Aug. 5 | ...do..... | 1 | ...do..... | 3 | Aug. 16 | 4 | 11 |
| 84 | 19 | ...do..... | Aug. 7 | 5 | Aug. 14 | 19 | ...do..... | 19 | 11 |
| 85 | 17 | ...do..... | ..do.....<br>Aug. 8 | 9<br>1 | ...do.....<br>Aug. 15 | 14<br>1 | ..do..... | 17 | 11 |
| 86 | 35 | Aug. 6 | ..do.....<br>Aug. 11 | 27<br>5 | ..do..... | 24 | ..do.....<br>Aug. 17 | 20<br>14 | 10<br>11 |
| 87 | 2 | ...do..... | Aug. 8 | 2 | ..do.....<br>Aug. 16 | 1<br>1 | Aug. 16<br>Aug. 17 | 1<br>1 | 10<br>11 |
| 88 | 13 | ...do..... | ..do.....<br>Aug. 10 | 9<br>4 | Aug. 15<br>Aug. 16 | 10<br>3 | Aug. 16<br>Aug. 17 | 8<br>5 | 10<br>11 |

TABLE XXIV.—*Second-brood eggs. Incubation period of eggs laid in rearing cages*—Continued.

| Number of apple. | Number of eggs. | Date of deposition. | Red ring. | | Black spot. | | Hatched. | | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date. | Number of eggs. | |
| | | | | | | | | | *Days.* |
| 89 | 46 | Aug. 7 | Aug. 9<br>Aug. 10<br>Aug. 12 | 8<br>27<br>9 | Aug. 16 | 46 | Aug. 17<br>Aug. 18 | 3<br>43 | 10<br>11 |
| 90 | 28 | ...do..... | Aug. 9<br>Aug. 10<br>Aug. 11 | 20<br>4<br>2 | ..do.....<br>Aug. 17 | 24<br>4 | Aug. 17<br>Aug. 18<br>Aug. 19 | 3<br>19<br>6 | 10<br>11<br>12 |
| 91 | 13 | ...do..... | Aug. 9<br>Aug. 10<br>Aug. 11 | 2<br>7<br>2 | Aug. 16<br>Aug. 17 | 7<br>6 | Aug. 18 | 13 | 11 |
| 92 | 3 | ...do..... | Aug. 10 | 1 | ..do.....<br>Aug. 18 | 2<br>1 | ..do..... | 2 | 11 |
| 93 | 24 | Aug. 9 | Aug. 11<br>Aug. 12 | 7<br>17 | ..do..... | 24 | Aug. 20 | 24 | 11 |
| 94 | 11 | ...do.... | ...do..... | 9 | Aug. 18<br>Aug. 19 | 8<br>5 | ..do .... | 11 | 11 |
| 95 | 35 | ...do..... | ...do..... | 23 | Aug. 18<br>Aug. 19 | 32<br>3 | ..do..... | 35 | 11 |
| 96 | 6 | ...do..... | ...do..... | 3 | Aug. 18 | 6 | ...do..... | 6 | 11 |
| 97 | 10 | ...do..... | ...do..... | 8 | ...do..... | 10 | ...do..... | 10 | 11 |
| 98 | 4 | Aug. 10 | Aug. 13 | 4 | Aug. 19 | 4 | ..do.....<br>Aug. 21 | 2<br>2 | 10<br>11 |
| 99 | 4 | ...do..... | ...do..... | 2 | ...do..... | 2 | Aug. 20<br>Aug. 21 | 2<br>1 | 10<br>11 |
| 100 | 5 | ...do..... | ...do..... | 4 | ...do..... | 5 | Aug. 20<br>Aug. 21 | 1<br>4 | 10<br>11 |
| 101 | 17 | ...do..... | ...do..... | 7 | ...do..... | 13 | ...do..... | 14 | 11 |
| 102 | 5 | Aug. 11 | Aug. 14 | 2 | Aug. 21 | 5 | Aug. 22<br>Aug. 23 | 1<br>3 | 11<br>12 |
| 103 | 9 | ...do..... | ...do..... | 9 | ...do..... | 9 | Aug. 22<br>Aug. 23 | 3<br>5 | 11<br>12 |
| 104 | 8 | ...do..... | ...do..... | 5 | ...do..... | 8 | Aug. 22<br>Aug. 23 | 6<br>2 | 11<br>12 |
| 105 | 4 | ...do..... | ...do..... | 3 | ..do.....<br>Aug. 22 | 2<br>2 | Aug. 22<br>Aug. 23 | 2<br>2 | 11<br>12 |
| 107 | 4 | Aug. 12 | Aug. 15 | 4 | Aug. 21<br>Aug. 22 | 3<br>1 | ..do..... | 3 | 11 |
| 108 | 17 | ...do..... | ...do..... | 10 | Aug. 21 | 17 | ...do..... | 17 | 11 |
| 109 | 5 | ...do..... | Aug. 16 | 4 | ...do..... | 5 | ...do..... | 5 | 11 |
| 110 | 8 | Aug. 13 | ...do..... | 6 | Aug. 22<br>Aug. 23 | 5<br>3 | ..do..... | 8 | 10 |
| 111 | 2 | ...do..... | Aug. 15 | 1 | Aug. 22 | 2 | Aug. 24 | 2 | 11 |
| 112 | 6 | ...do..... | Aug. 17 | 6 | ..do.....<br>Aug. 23 | 4<br>2 | ...do.....<br>Aug. 25 | 5<br>1 | 11<br>12 |
| 113 | 27 | Aug. 14 | ...do..... | 27 | ...do..... | 27 | Aug. 24<br>Aug. 25 | 19<br>8 | 10<br>11 |
| 114 | 30 | ...do..... | ...do..... | 30 | ...do..... | 30 | Aug. 24<br>Aug. 25 | 22<br>8 | 10<br>11 |
| 115 | 28 | ...do..... | ...do..... | 28 | ...do..... | 28 | Aug. 24<br>Aug. 25 | 22<br>6 | 10<br>11 |
| 116 | 49 | Aug. 15 | ...do..... | 49 | Aug. 24 | 49 | ...do..... | 48 | 10 |
| 117 | 51 | ...do..... | ...do..... | 51 | ...do..... | 51 | ...do..... | 51 | 10 |
| 118 | 37 | ...do..... | ...do..... | 37 | ...do..... | 37 | ..do.....<br>Aug. 26 | 34<br>3 | 10<br>11 |
| 119 | 81 | Aug. 16 | Aug. 18<br>Aug. 19 | 26<br>55 | ...do.....<br>Aug. 25 | 19<br>62 | ...do.....<br>Aug. 27 | 56<br>25 | 10<br>11 |
| 120 | 60 | ...do..... | Aug. 18<br>Aug. 19 | 30<br>30 | Aug. 24<br>Aug. 25 | 29<br>31 | Aug. 26<br>Aug. 27 | 30<br>30 | 10<br>11 |
| 121 | 46 | ...do..... | Aug. 18<br>Aug. 19 | 20<br>26 | Aug. 24<br>Aug. 25 | 40<br>6 | Aug. 26<br>Aug. 27 | 44<br>2 | 10<br>11 |
| 122 | 11 | Aug. 17 | ..do.....<br>Aug. 21 | 5<br>6 | ...do.....<br>Aug. 26 | 5<br>5 | ...do.....<br>Aug. 28 | 7<br>4 | 10<br>11 |
| 123 | 23 | ...do..... | Aug. 19<br>Aug. 21 | 10<br>12 | Aug. 25<br>Aug. 26 | 11<br>12 | Aug. 27<br>Aug. 28 | 15<br>8 | 10<br>11 |
| 124 | 19 | ...do..... | Aug. 19<br>Aug. 21 | 8<br>11 | Aug. 25<br>Aug. 26 | 8<br>11 | Aug. 27<br>Aug. 28 | 12<br>7 | 10<br>11 |
| 125 | 3 | Aug. 18 | Aug. 20<br>Aug. 21 | 1<br>2 | ...do.....<br>Aug. 27 | 2<br>1 | Aug. 30 | 3 | 12 |
| 126 | 4 | ...do..... | Aug. 20<br>Aug. 21 | 2<br>2 | Aug. 26<br>Aug. 27 | 1<br>3 | ..do..... | 4 | 12 |
| 127 | 4 | ...do..... | Aug. 20<br>Aug. 21 | 2<br>2 | ...do.....<br>Aug. 28 | 3<br>1 | Aug. 29<br>Aug. 30 | 2<br>1 | 11<br>12 |
| 128 | 11 | Aug. 19 | ...do..... | 11 | Aug. 27<br>Aug. 28 | 9<br>2 | ..do..... | 11 | 11 |

TABLE XXIV.—*Second-brood eggs. Incubation period of eggs laid in rearing cages*—Continued.

| Number of apple. | Number of eggs. | Date of deposition. | Red ring. | | Black spot. | | Hatched. | | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date. | Number of eggs. | |
| | | | | | | | | | *Days.* |
| 129 | 12 | Aug. 20 | Aug. 21<br>Aug. 22<br>Aug. 23<br>Aug. 24 | 3<br>3<br>2<br>1 | Aug. 27<br>Aug. 28<br>Aug. 29 | 3<br>1<br>8 | Aug. 30<br>Aug. 31 | 7<br>5 | 10<br>11 |
| 130 | 16 | ...do..... | Aug. 23<br>Aug. 24 | 5<br>3 | Aug. 28<br>Aug. 29 | 2<br>14 | Aug. 30<br>Aug. 31 | 10<br>6 | 10<br>11 |
| 131 | 8 | Aug. 21 | ..do.....<br>Aug. 25 | 1<br>2 | Aug. 30 | 8 | Sept. 1 | 8 | 11 |
| 132 | 7 | ...do..... | Aug. 24 | 2 | ...do..... | 7 | ...do..... | 7 | 11 |
| 133 | 9 | Aug. 22 | ...do..... | 5 | ..do.....<br>Aug. 31 | 7<br>1 | ..do..... | 9 | 10 |
| 134 | 5 | ...do..... | ...do..... | 3 | Aug. 30 | 5 | ...do..... | 5 | 10 |
| 135 | 2 | ...do..... | ...do..... | 1 | Aug. 31 | 1 | Sept. 2 | 1 | 11 |
| 136 | 7 | Aug. 23 | Aug. 25 | 4 | ..do.....<br>Sept. 1 | 4<br>3 | ..do..... | 5 | 10 |
| 137 | 19 | ...do..... | Aug. 24<br>Aug. 26 | 4<br>8 | ..do..... | 19 | ..do.....<br>Sept. 3 | 15<br>4 | 10<br>11 |
| 138 | 8 | ...do..... | Aug. 25<br>Aug. 26 | 3<br>3 | ..do..... | 8 | Sept. 2<br>Sept. 3<br>Sept. 4 | 3<br>3<br>2 | 10<br>11<br>12 |
| 139 | 9 | Aug. 24 | ...do..... | 3 | Sept. 2<br>Sept. 3 | 2<br>2 | ..do.....<br>Sept. 5<br>Sept. 6 | 7<br>1<br>1 | 11<br>12<br>13 |
| 140 | 11 | ...do..... | ...do..... | 10 | Sept. 2<br>Sept. 3 | 9<br>2 | Sept. 4<br>Sept. 5 | 9<br>2 | 11<br>12 |
| 141 | 3 | ...do..... | ...do..... | 1 | Sept. 2 | 3 | Sept. 4 | 3 | 11 |
| 142 | 6 | Aug. 25 | Aug. 28 | 4 | Sept. 3<br>Sept. 4 | 4<br>2 | Sept. 5<br>Sept. 6 | 2<br>2 | 11<br>12 |
| 143 | 2 | ...do..... | ...do..... | 2 | Sept. 3 | 2 | Sept. 5<br>Sept. 6 | 1<br>1 | 11<br>12 |
| 144 | 4 | ...do..... | ...do..... | 3 | ..do.....<br>Sept. 4 | 2<br>1 | ..do..... | 3 | 12 |
| 145 | 4 | Aug. 26 | Aug. 29 | 1 | Sept. 5<br>Sept. 6 | 2<br>2 | ...do.....<br>Sept. 7 | 3<br>1 | 11<br>12 |
| 146 | 21 | ...do..... | ...do..... | 10 | Sept. 5<br>Sept. 6 | 17<br>4 | ..do..... | 21 | 12 |
| 147 | 19 | ...do..... | ...do..... | 8 | Sept. 5 | 19 | ...do..... | 17 | 12 |
| 148 | 11 | Aug. 27 | Aug. 30 | 2 | Sept. 6 | 11 | Sept. 8 | 11 | 12 |
| 149 | 6 | ...do..... | ...do..... | 3 | ...do..... | 6 | ...do..... | 6 | 12 |
| 150 | 5 | Aug. 28 | ...do..... | 2 | Sept. 7 | 5 | Sept. 9 | 5 | 12 |
| 151 | 4 | ...do..... | ...do..... | 2 | ...do..... | 4 | ...do..... | 4 | 12 |
| 152 | 12 | Aug. 29 | Aug. 31 | 3 | Sept. 8<br>Sept. 9 | 10<br>2 | Sept. 10<br>Sept. 11 | 9<br>3 | 12<br>12 |
| 153 | 8 | ...do..... | ...do..... | 7 | Sept. 8<br>Sept. 9 | 3<br>1 | Sept 10 | 3 | 12 |
| 154 | 23 | Aug. 30 | Sept. 2 | 19 | ...do....<br>Sept. 10 | 2<br>21 | Sept. 11<br>Sept. 12 | 12<br>9 | 12<br>13 |
| 155 | 4 | ...do..... | ...do..... | 4 | Sept. 9<br>Sept. 10 | 1<br>3 | Sept. 11<br>Sept. 12 | 2<br>2 | 12<br>13 |
| 156 | 14 | ...do..... | ...do..... | 11 | Sept. 9<br>Sept. 10 | 6<br>8 | Sept. 11<br>Sept. 12<br>Sept. 13 | 11<br>1<br>2 | 12<br>13<br>14 |
| 157 | 2 | Aug. 31 | Sept. 3<br>Sept. 4 | 1<br>1 | ..do..... | 2 | Sept. 12 | 2 | 12 |
| 158 | 2 | ...do..... | ...do..... | 12 | Sept. 11 | 2 | ...do..... | 1 | 12 |
| 159 | 2 | Sept. 2 | Sept. 6 | 2 | Sept. 13 | 2 | Sept. 16 | 2 | 14 |
| 160 | 8 | ...do..... | ...do..... | 7 | ..do.....<br>Sept. 14 | 4<br>2 | Sept. 15<br>Sept. 16 | 2<br>4 | 13<br>14 |
| 162 | 11 | ...do..... | ...do..... | 7 | Sept. 13 | 11 | ...do..... | 11 | 14 |
| 163 | 8 | Sept. 3 | Sept. 7 | 8 | Sept. 14<br>Sept. 15 | 6<br>2 | ...do ....<br>Sept. 17 | 6<br>2 | 13<br>14 |
| 164 | 5 | ...do..... | ...do..... | 5 | Sept. 14 | 5 | Sept. 16<br>Sept. 17 | 2<br>3 | 13<br>14 |
| 165 | 7 | ...do..... | ...do..... | 7 | ...do..... | 7 | Sept. 16<br>Sept. 17 | 2<br>5 | 13<br>14 |
| 166 | 5 | ...do..... | ...do..... | 5 | Sept. 15 | 5 | ..do.....<br>Sept. 18 | 4<br>1 | 13<br>14 |
| 167 | 3 | Sept. 4 | Sept. 8 | 3 | ...do..... | 5 | Sept. 17<br>Sept. 18 | 2<br>1 | 13<br>14 |
| 168 | 3 | Sept. 5 | Sept. 9 | 1 | Sept. 17 | 2 | Sept. 19 | 2 | 14 |
| 169 | 2 | ...do..... | ...do..... | 2 | ...do..... | 2 | ...do..... | 2 | 14 |
| 170 | 1 | Sept. 7 | Sept. 10 | 1 | Sept. 19 | 1 | Sept. 22 | 1 | 15 |
| 171 | 11 | Sept. 9 | Sept. 11 | 7 | Sept. 21 | 11 | Sept. 24 | 11 | 15 |
| 172 | 5 | ...do..... | ...do..... | 1 | ...do..... | 2 | ...do..... | 2 | 15 |
| 173 | 4 | ...do..... | Sept. 13 | 2 | ...do..... | 2 | ...do..... | 2 | 15 |

TABLE XXIV.—*Second-brood eggs. Incubation period of eggs laid in rearing cages*—Continued.

| Number of apple. | Number of eggs. | Date of deposition. | Red ring. |  | Black spot. |  | Hatched. |  | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date. | Number of eggs. |  |
|  |  |  |  |  |  |  |  |  | *Days.* |
| 174 | 8 | Sept. 10 | Sept. 13 | 8 | Sept. 22 | 3 | Sept. 25 | 2 | 15 |
|  |  |  |  |  | Sept. 23 | 2 | Sept. 27 | 3 | 17 |
| 175 | 3 | ...do..... | ...do..... | 3 | Sept. 22 | 2 | Sept. 25 | 2 | 15 |
|  |  |  |  |  | Sept. 23 | 1 | Sept. 26 | 1 | 16 |
| 176 | 13 | ...do..... | ...do..... | 13 | Sept. 22 | 11 | Sept. 25 | 10 | 15 |
|  |  |  |  |  | Sept. 23 | 2 | Sept. 26 | 3 | 16 |
| 178 | 12 | Sept. 11 | Sept. 15 | 6 | ...do..... | 3 | Sept. 25 | 1 | 14 |
|  |  |  | Sept. 17 | 3 | Sept. 24 | 9 | Sept. 26 | 11 | 15 |
| 179 | 1 | Sept. 12 | Sept. 15 | 1 | Sept. 26 | 1 | Sept. 27 | 1 | 15 |
| 180 | 5 | Sept. 14 | Sept. 18 | 2 | ...do..... | 5 | Sept. 29 | 5 | 15 |
| 181 | 6 | ...do..... | ...do..... | 6 | ..do..... | 5 | ..do..... | 6 | 15 |
|  |  |  |  |  | Sept. 27 | 1 |  |  |  |
| 182 | 13 | ...do..... | ...do..... | 7 | Sept. 26 | 13 | ...do..... | 13 | 15 |
| 183 | 1 | Sept. 15 | Sept. 19 | 1 | Sept. 27 | 1 | Sept. 30 | 1 | 15 |
| 184 | 6 | Sept. 17 | Sept. 20 | 6 | Sept. 30 | 6 | Oct. 2 | 6 | 15 |
| 185 | 3 | ...do..... | ...do..... | 5 | ...do..... | 7 | ...do..... | 7 | 15 |
| 186 | 3 | Sept. 18 | Sept. 22 | 2 | Oct. 1 | 3 | Oct. 3 | 3 | 15 |
| 187 | 3 | ...do..... | ...do..... | 3 | ...do..... | 2 | ...do..... | 2 | 15 |
| 188 | 3 | Sept. 21 | Sept. 24 | 3 | Oct. 4 | 2 | Oct. 6 | 2 | 15 |
| 189 | 3 | Sept. 22 | Sept. 25* | 3 | Oct. 6 | 3 | Oct. 8 | 3 | 16 |

The length of the egg stage ranged from 7 to 17 days, with an average of 10.92 days. Very little difference in the length of the stage is shown by Table XXIV for the 78 days or period of ovipositing by the first-brood moths. The red ring appeared from 2 to 3 days after deposition usually, the black spot from 6 to 10 days.

TABLE XXV.—*Incubation period of second-brood eggs. Summary of Table XXIV.*

| Observation. | For appearance of red ring. | For appearance of black spot. | For incubation. |
|---|---|---|---|
|  | *Days.* | *Days.* | *Days.* |
| Average.......... | 2.64 | 9.24 | 10.92 |
| Maximum........ | 9 | 15 | 17 |
| Minimum......... | 1 | 5 | 7 |

## SECOND BROOD OF LARVÆ.

*Feeding period.*—As mentioned under the egg stage, eggs were obtained from July 9 to September 25, a period of 78 days, and were hatching from about July 19 to October 8. The feeding periods were observed on a number of these at various intervals and developed normally and spun cocoons in the rearing cages in which they passed the winter. The details of these records are given in Table XXVI.

TABLE XXVI.—*Larvæ of second brood. Period of feeding of larvæ in rearing cages.*

| No. of larva. | Date of— |  | Days of feeding. | No. of larva. | Date of— |  | Days of feeding. |
|---|---|---|---|---|---|---|---|
|  | Hatching. | Leaving fruit. |  |  | Hatching. | Leaving fruit. |  |
| 1 | July 20 | Aug. 29 | 40 | 43 | Aug. 20 | Sept. 20 | 31 |
| 2 | July 21 | ...do..... | 39 | 44 | ...do..... | Sept. 25 | 36 |
| 3 | ...do..... | ...do..... | 39 | 45 | ...do..... | Sept. 24 | 35 |
| 4 | ...do..... | Sept. 11 | 52 | 46 | ...do..... | Sept. 29 | 40 |
| 5 | ...do..... | Sept. 13 | 54 | 47 | ...do..... | Sept. 28 | 39 |
| 6 | ...do..... | Aug. 30 | 40 | 48 | ...do..... | Sept. 23 | 34 |
| 7 | ...do..... | Aug. 31 | 41 | 49 | Aug. 21 | Oct. 7 | 48 |
| 8 | ...do..... | ...do..... | 41 | 50 | Aug. 22 | Oct. 18 | 57 |
| 9 | ...do..... | Sept. 2 | 43 | 51 | ...do..... | Sept. 25 | 34 |
| 10 | ...do..... | Aug. 31 | 41 | 52 | ...do..... | Sept. 29 | 38 |
| 11 | July 26 | Sept. 17 | 53 | 53 | Aug. 23 | Sept. 28 | 36 |
| 12 | July 29 | Sept. 5 | 38 | 54 | ...do..... | Sept. 30 | 38 |
| 13 | July 31 | Sept. 28 | 59 | 55 | ...do..... | Sept. 26 | 34 |
| 14 | Aug. 10 | Sept. 15 | 36 | 56 | ...do..... | Oct. 6 | 44 |
| 15 | ...do..... | Sept. 21 | 42 | 57 | Aug. 24 | Sept. 26 | 35 |
| 16 | Aug. 11 | Sept. 15 | 35 | 58 | ...do..... | Sept. 25 | 34 |
| 17 | Aug. 12 | Sept. 20 | 39 | 59 | ...do..... | Oct. 12 | 49 |
| 18 | Aug. 11 | Sept. 10 | 30 | 60 | ...do..... | Oct. 15 | 52 |
| 19 | Aug. 12 | Sept. 13 | 32 | 61 | Aug. 25 | Oct. 10 | 46 |
| 20 | Aug. 13 | Sept. 26 | 44 | 62 | ...do..... | Oct. 7 | 43 |
| 21 | Aug. 14 | Sept. 13 | 30 | 63 | ...do..... | Oct. 6 | 42 |
| 22 | Aug. 15 | Sept. 17 | 33 | 64 | Aug. 27 | Sept. 27 | 31 |
| 23 | Aug. 14 | Sept. 15 | 32 | 65 | ...do..... | Oct. 6 | 40 |
| 24 | Aug. 15 | Sept. 25 | 41 | 66 | Aug. 30 | Oct. 7 | 38 |
| 25 | ...do..... | Sept. 28 | 44 | 67 | ...do..... | Sept. 29 | 30 |
| 26 | Aug. 14 | Sept. 21 | 38 | 68 | ...do..... | Oct. 16 | 47 |
| 27 | Aug. 15 | Sept. 19 | 35 | 69 | ...do..... | Oct. 7 | 38 |
| 28 | ...do..... | Sept. 18 | 34 | 70 | ...do..... | Oct. 21 | 52 |
| 29 | Aug. 16 | Sept. 30 | 45 | 71 | Sept. 1 | Oct. 9 | 38 |
| 30 | ...do..... | Sept. 19 | 34 | 72 | ...do..... | Oct. 13 | 42 |
| 31 | ...do..... | ...do..... | 34 | 73 | Sept. 2 | Oct. 16 | 44 |
| 32 | Aug. 17 | Oct. 1 | 45 | 74 | ...do..... | Oct. 18 | 46 |
| 33 | ...do..... | Sept. 25 | 39 | 75 | Sept. 3 | Oct. 19 | 46 |
| 34 | Aug. 18 | Sept. 30 | 43 | 76 | Sept. 4 | ...do..... | 45 |
| 35 | Aug. 17 | Sept. 24 | 38 | 77 | ...do..... | Oct. 5 | 31 |
| 36 | Aug. 18 | Sept. 27 | 40 | 78 | Sept. 7 | Oct. 19 | 42 |
| 37 | ...do..... | Sept. 22 | 35 | 79 | Sept. 10 | Oct. 18 | 38 |
| 38 | ...do..... | Sept. 24 | 37 | 80 | Sept. 12 | Oct. 22 | 40 |
| 39 | Aug. 20 | Oct. 5 | 48 | 81 | Sept. 16 | Oct. 21 | 35 |
| 40 | ...do..... | Sept. 26 | 37 | 82 | Sept. 17 | Oct. 24 | 37 |
| 41 | ...do..... | Sept. 30 | 41 | 83 | Sept. 25 | Nov. 4 | 40 |
| 42 | ...do..... | Oct. 3 | 44 |  |  |  |  |

TABLE XXVII.—*Feeding period of larvæ of the second brood. Summary of Table XXVI.*

| Observations. | Feeding periods. |
|---|---|
| Average......... | 40 |
| Maximum........ | 59 |
| Minimum......... | 30 |

The feeding periods of the larvæ under observation ranged from 30 to 59 days, with an average of 40 days. It will be seen by comparing the records of the first-brood larvæ with these that practically no difference existed between the length of the feeding periods of the first and the second-brood larvæ.

*Time of leaving the fruit for winter.*—The earliest second-brood larvæ to leave the fruit in the cages to hibernate did so on August 29, but were probably one or two weeks earlier in the field. The last larvæ in the cages to leave the fruit did so on November 4, which is quite close to the time the last larvæ had matured in the field according to the band record.

The senior author observed a half-grown larva feeding in an apple in a tree November 30, 1911, and it is possible larvæ could live much longer in the field if the fruit was not picked or would fall from the trees.

### REVIEW OF LIFE-HISTORY WORK OF 1910.

During 1910 the life-history work of both broods of the codling moth was carefully worked out and results of these observations are shown in the diagram, figure 31. This diagram is an effort to depict the condition of the insect in orchards during the season as based on data obtained in the laboratory. Spring pupæ appeared shortly after the middle of February and continued to appear until June, reaching a maximum about April 4. Moths began to emerge March 28 and continued emerging until June 9, with an average maximum May 4. Oviposition of the first-brood eggs extended from April 10 to June 20 with a maximum about May 16, while the larvæ of the first brood began to hatch April 26 and continued hatching until July 22, reaching a maximum about May 29. The larvæ of the first brood cocooned from May 28 up to August 14 with a maximum about July 3. About June 4 the first-brood pupæ were present and continued until September 3, reaching a maximum about July 14. Emergence of the first-brood moths commenced June 22 and lasted three months or until September 22, with a maximum about August 4. Second-brood eggs were deposited from July 1 until September 28, reaching a

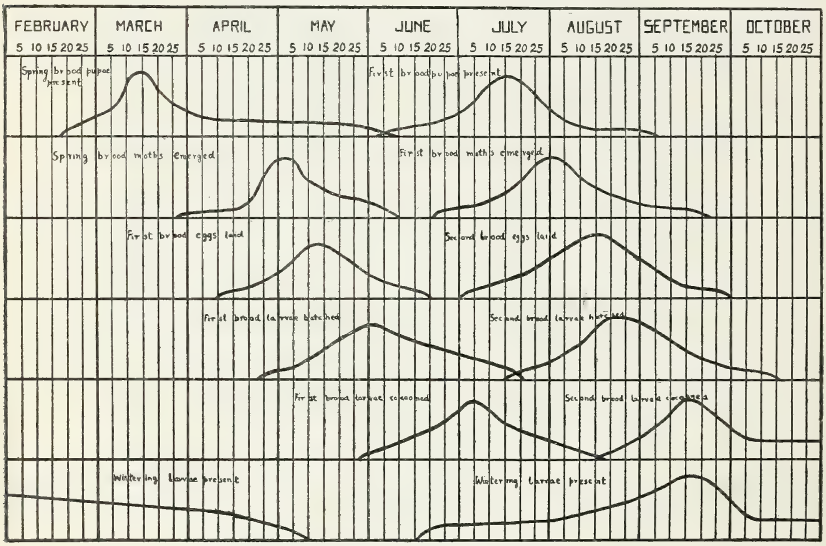

FIG. 31.—Diagram showing seasonal history of the codling moth during the season of 1910. (Original.)

maximum about August 11, while the second-brood larvæ hatched from July 13 until October 12 with a maximum about August 20. The second-brood larvæ cocooned August 16 and on throughout the winter, with a maximum about September 16. The wintering larvæ of the first brood "to spin cocoons" began to do so about June 15, but by far the largest number of these came from the second or true overwintering brood. The life cycle of the codling moth from the first appearance of the spring pupæ until the last larva of the first brood cocooned occupied about six months. The second-brood life cycle from the first appearance of the first-brood pupæ up to the cocooning of the wintering larvæ in 1911 occupied a period of over eleven months.

## SEASONAL-HISTORY STUDIES FOR 1911.

### SPRING BROOD OF PUPÆ.

*Time of pupation.*—Records for the spring brood were kept in two series, one lot in small gelatin capsules, size No. 0, punctured with a pin, and the other in vials. Those in the capsules were taken from under bands in February and out of the larvæ thus secured only 41 per cent pupated. Of those that pupated 21.7 per cent died, the majority of these being early pupating individuals. The first larva pupated on March 2, the second March 14, and none after that until the last week of the month. Pupation continued until May 11, on which date the last larva became a pupa. The first adult appeared April 18 and the last June 8. Thus the actual period of time when pupæ were present extended from March 2 to June 8, or 98 days. In the field, however, adults were emerging from March 24 to June 20; thus pupæ were present from about February 12 until June 20, or 128 days. The longest pupal stage was 49 days, the shortest 30, and the average 41.9 days. Figure 32 shows the time of pupation for both capsule and vial material and also daily mean temperature. These data were compiled from records of 156 individuals.

*Second series of larvæ.*—Larvæ were taken from bands in the fall of 1910 and placed in vials, where they remained through the winter. Of these 25.2 per cent died before pupating and of the ones that developed into pupæ 23.2 per cent perished. The earliest pupa occurred March 16 and the latest May 11. The earliest adult issued April 26 and the latest June 11. Therefore the period when pupæ were present, March 16 to June 11, amounted to 87 days. The shortest pupal stage was 31 days, the longest 56, and the average 43.2 days. This exceeds the average for the capsule series by 1.3 days. There were 66 individuals in the vial series, of which 32 were males and one escaped before its sex could be determined. No attempt was made to credit any certain sex to the larvæ while in that stage as was done in 1910. The average male pupal stage was 41.8 days, while that of the female was 44.3 days, or 2.5 days longer. In summarizing the two series we find that the earliest pupa occurred March 2, the latest pupa May 11, the earliest adult April 18, and the last adult June 11. The shortest pupal stage was 30 days, the longest 56, and the average 42.4 days. From the total adult emergence record (fig. 33) it will be seen that the earliest adult emerged on March 24 and the last on June 20, so that by using the average pupal period the earliest possible pupa must have occurred about February 9, and thus the theoretical span of the pupal period included the time between February 9 and June 20, or 131 days. Tables XXVIII and XXIX show, respectively, the pupal stages in the capsules and vials.

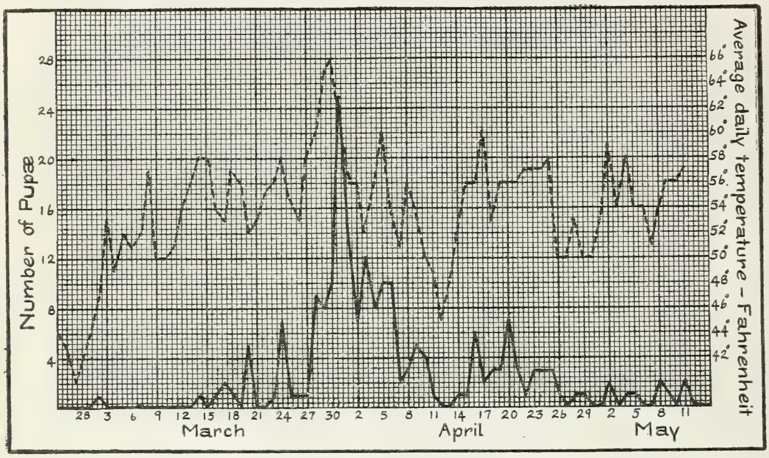

FIG. 32.—Diagram showing pupation of spring brood of larvæ, 1911. (Original.)

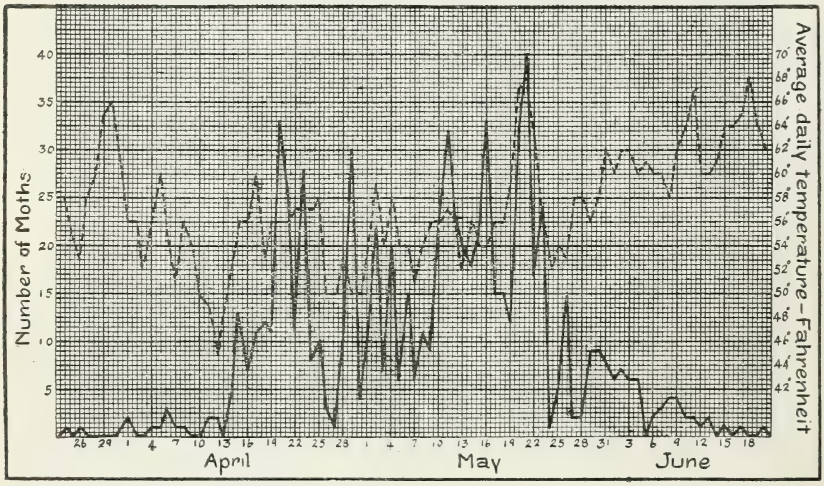

FIG. 33.—Diagram showing emergence of moths; overwintering brood of 1911. (Original.)

TABLE XXVIII.—*Spring brood of pupæ. Length of pupal stage of overwintering larvæ collected under bands in February, 1911, and reared in capsules.*

| No. of individual. | Date of— | | Length of pupal stage. | No. of individual. | Date of— | | Length of pupal stage. |
|---|---|---|---|---|---|---|---|
| | Pupation. | Emergence. | | | Pupation. | Emergence. | |
| | | | *Days.* | | | | *Days.* |
| 1 | Mar. 2 | Apr. 20 | 49 | 46 | Apr. 3 | May 18 | 45 |
| 2 | Mar. 14 | Apr. 18 | 35 | 47 | ...do..... | May 19 | 46 |
| 3 | Mar. 26 | May 6 | 41 | 48 | ...do..... | May 16 | 43 |
| 4 | Mar. 28 | May 10 | 43 | 49 | ...do..... | ...do..... | 43 |
| 5 | Mar. 29 | May 6 | 38 | 50 | ...do..... | May 20 | 47 |
| 6 | ...do..... | May 9 | 41 | 51 | Apr. 4 | May 19 | 45 |
| 7 | ...do..... | May 10 | 42 | 52 | ...do..... | May 17 | 43 |
| 8 | ...do..... | ...do..... | 42 | 53 | ...do..... | May 18 | 44 |
| 9 | Mar. 30 | May 13 | 44 | 54 | Apr. 5 | May 15 | 40 |
| 10 | ...do..... | ...do..... | 44 | 55 | ...do..... | May 18 | 43 |
| 11 | ...do..... | May 10 | 41 | 56 | ...do..... | May 19 | 44 |
| 12 | ...do..... | May 12 | 43 | 57 | ...do..... | May 20 | 45 |
| 13 | Mar. 13 | ...do..... | 42 | 58 | ...do..... | ...do..... | 45 |
| 14 | Mar. 31 | May 13 | 43 | 59 | ...do..... | May 18 | 43 |
| 15 | ...do..... | ...do..... | 43 | 60 | Apr. 6 | May 20 | 44 |
| 16 | ...do..... | ...do..... | 43 | 61 | ...do..... | May 18 | 42 |
| 17 | ...do..... | May 15 | 45 | 62 | ...do..... | May 20 | 44 |
| 18 | ...do..... | May 12 | 42 | 63 | ...do..... | ...do..... | 44 |
| 19 | ...do..... | May 14 | 44 | 64 | ...do..... | May 19 | 43 |
| 20 | ...do..... | May 12 | 42 | 65 | ...do..... | May 20 | 44 |
| 21 | ...do..... | ...do..... | 42 | 66 | ...do..... | ...do..... | 44 |
| 22 | ...do..... | May 14 | 44 | 67 | Apr. 9 | May 21 | 42 |
| 23 | ...do..... | May 15 | 45 | 68 | ...do..... | ...do..... | 42 |
| 24 | ...do..... | May 14 | 44 | 69 | Apr. 10 | ...do..... | 41 |
| 25 | Mar. 25 | ...do..... | 44 | 70 | ...do..... | ...do..... | 41 |
| 26 | Mar. 31 | May 12 | 42 | 71 | ...do..... | ...do..... | 41 |
| 27 | ...do..... | May 14 | 44 | 72 | Apr. 14 | May 22 | 38 |
| 28 | Apr. 1 | May 11 | 40 | 73 | Apr. 15 | May 23 | 38 |
| 29 | ...do..... | May 16 | 45 | 74 | Apr. 16 | ...do..... | 37 |
| 30 | ...do..... | May 14 | 43 | 75 | ...do..... | May 22 | 36 |
| 31 | ...do..... | May 15 | 44 | 76 | Apr. 17 | May 24 | 37 |
| 32 | ...do..... | May 16 | 45 | 77 | Apr. 19 | May 27 | 38 |
| 33 | ...do..... | May 13 | 42 | 78 | Apr. 20 | May 26 | 36 |
| 34 | ...do..... | May 16 | 46 | 79 | ...do..... | ...do..... | 36 |
| 35 | ...do..... | May 13 | 42 | 80 | ...do..... | May 31 | 41 |
| 36 | Apr. 2 | May 14 | 42 | 81 | Apr. 21 | ...do..... | 40 |
| 37 | ...do..... | May 15 | 43 | 82 | ...do..... | ...do..... | 40 |
| 38 | ...do..... | ...do..... | 43 | 83 | Apr. 24 | June 1 | 38 |
| 39 | ...do..... | May 14 | 42 | 84 | ...do..... | ...do..... | 38 |
| 40 | ...do..... | ...do..... | 42 | 85 | Apr. 25 | May 31 | 36 |
| 41 | ...do..... | May 15 | 43 | 86 | Apr. 26 | June 4 | 39 |
| 42 | Apr. 3 | May 16 | 43 | 87 | Apr. 28 | June 3 | 36 |
| 43 | ...do..... | May 19 | 46 | 88 | May 2 | June 6 | 35 |
| 44 | ...do..... | May 16 | 43 | 89 | ...do..... | June 4 | 33 |
| 45 | ...do..... | May 18 | 45 | 90 | May 9 | June 8 | 30 |

TABLE XXIX.—*Spring brood of pupæ. Length of the pupal stage of overwintering larvæ collected from banded trees in 1910 and reared in vials.*

| No. of individual. | Date of— Pupation. | Date of— Emergence. | Sex. | Length of pupal stage. | No. of individual. | Date of— Pupation. | Date of— Emergence. | Sex. | Length of pupal stage. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Days.* | | | | | *Days.* |
| 1 | Mar. 14 | May 6 | ♂ | 43 | 34 | Mar. 31 | May 16 | ...... | 46 |
| 2 | Mar. 16 | Apr. 26 | ♂ | 41 | 35 | ...do..... | May 12 | ♂ | 42 |
| 3 | Mar. 17 | Apr. 29 | ♂ | 43 | 36 | ...do..... | May 16 | ♀ | 47 |
| 4 | ...do..... | Apr. 28 | ♂ | 42 | 37 | ...do..... | May 18 | ♂ | 48 |
| 5 | Mar. 18 | Apr. 30 | ♀ | 43 | 38 | ...do..... | May 16 | ♂ | 46 |
| 6 | Mar. 20 | May 1 | ♀ | 42 | 39 | Apr. 1 | ...do..... | ♀ | 45 |
| 7 | ...do..... | May 3 | ♂ | 44 | 40 | ...do..... | May 18 | ♂ | 47 |
| 8 | ...do..... | May 2 | ♂ | 43 | 41 | ...do..... | May 20 | ♀ | 49 |
| 9 | ...do..... | May 1 | ♂ | 43 | 42 | ...do..... | May 27 | ♀ | 56 |
| 10 | ...do..... | Apr. 30 | ♀ | 41 | 43 | Apr. 3 | May 19 | ♂ | 46 |
| 11 | Mar. 23 | May 4 | ♀ | 44 | 44 | ...do..... | May 20 | ♀ | 47 |
| 12 | Mar. 24 | May 5 | ♂ | 44 | 45 | Apr. 5 | May 21 | ♀ | 47 |
| 13 | ...do..... | May 8 | ♀ | 45 | 46 | Apr. 4 | ...do..... | ♀ | 47 |
| 14 | ...do..... | May 5 | ♂ | 42 | 47 | Apr. 5 | ...do..... | ♀ | 46 |
| 15 | Mar. 25 | ...do..... | ♀ | 41 | 48 | ...do..... | ...do..... | ♀ | 46 |
| 16 | Mar. 26 | May 8 | ♂ | 42 | 49 | Apr. 8 | May 22 | ♂ | 44 |
| 17 | Mar. 28 | ...do..... | ♂ | 41 | 50 | ...do..... | ...do..... | ♀ | 44 |
| 18 | ...do..... | May 9 | ♀ | 42 | 51 | Apr. 9 | May 21 | ♀ | 42 |
| 19 | ...do..... | May 10 | ♀ | 43 | 52 | ...do..... | May 22 | ♀ | 43 |
| 20 | ...do..... | May 6 | ♂ | 39 | 53 | ...do..... | May 18 | ♂ | 39 |
| 21 | ...do..... | May 11 | ♂ | 44 | 54 | Apr. 10 | May 22 | ♂ | 42 |
| 22 | ...do..... | May 10 | ♂ | 43 | 55 | Apr. 11 | ...do..... | ♂ | 41 |
| 23 | Mar. 29 | May 11 | ♀ | 43 | 56 | Apr. 16 | May 26 | ♂ | 40 |
| 24 | ...do..... | May 10 | ♀ | 42 | 57 | ...do..... | May 23 | ♂ | 37 |
| 25 | ...do..... | ...do..... | ♀ | 43 | 58 | ...do..... | May 30 | ♂ | 44 |
| 26 | ...do..... | May 12 | ♀ | 44 | 59 | Apr. 18 | May 26 | ♂ | 38 |
| 27 | Mar. 30 | May 13 | ♀ | 45 | 60 | ...do..... | May 28 | ♀ | 40 |
| 28 | ...do..... | May 15 | ♀ | 46 | 61 | Apr. 20 | May 29 | ♀ | 39 |
| 29 | Mar. 31 | May 13 | ♂ | 43 | 62 | Apr. 21 | ...do..... | ♀ | 38 |
| 30 | ...do..... | May 16 | ♀ | 46 | 63 | Apr. 22 | May 30 | ♂ | 38 |
| 31 | ...do..... | ...do..... | ♀ | 46 | 64 | Apr. 23 | June 1 | ♂ | 39 |
| 32 | ...do..... | ...do..... | ♀ | 46 | 65 | ...do..... | ...do..... | ♂ | 39 |
| 33 | ...do..... | ...do..... | ♀ | 46 | 66 | May 11 | June 11 | ♂ | 31 |

Table XXX shows the variations in the length of the pupal period for 156 individuals as recorded in Tables XXVIII and XXIX:

TABLE XXX.—*Spring brood of pupæ. Variation in the length of the pupal period as recorded in Tables XXVIII and XXIX.*

| Pupæ. | Days. | Pupæ. | Days. | Pupæ. | Days. | Pupæ. | Days. |
|---|---|---|---|---|---|---|---|
| 1 | 30 | 3 | 37 | 24 | 42 | 6 | 47 |
| 1 | 31 | 9 | 38 | 28 | 43 | 1 | 48 |
| 1 | 33 | 6 | 39 | 23 | 44 | 2 | 49 |
| 2 | 35 | 6 | 40 | 12 | 45 | 1 | 56 |
| 5 | 36 | 12 | 41 | 13 | 46 | | |

Tables XXVIII and XXIX show that individuals which pupated early usually remained longer in the pupal state than those which later became pupæ.

*Temperature conditions.*—The temperature conditions influencing the pupal periods of the spring brood of pupæ are shown in the following table:

**Table** XXXI.—*Temperature conditions influencing the pupal period of the spring brood in degrees Fahrenheit.*

| Month. | Maximum. | Minimum. | Mean. | Departure from normal. |
|---|---|---|---|---|
| | ° *F.* | ° *F.* | ° *F.* | |
| March | 63.3 | 46.0 | 54.6 | +0.9 |
| April | 65.0 | 42.7 | 53.8 | −2.5 |
| May | 69.2 | 43.8 | 56.5 | −4.2 |
| Average | 65.8 | 44.2 | 55.0 | |

SPRING BROOD OF MOTHS.

*Time of emergence of moths in the spring.*—Figure 33 shows graphically the time of emergence and the relative abundance of moths of the spring brood with the corresponding daily mean temperature in degrees Fahrenheit. The records for these observations are given in Table XXXII.

**Table** XXXII.—*Emergence of spring moths, 1911, from wintering material collected on banded trees during 1910.*

| Date. | Number of moths. | Date. | Number of moths. | Date. | Number of moths. | Date. | Number of moths. |
|---|---|---|---|---|---|---|---|
| Mar. 24 | 1 | Apr. 16 | 7 | May 9 | 9 | June 1 | 6 |
| Mar. 25 | 0 | Apr. 17 | 11 | May 10 | 22 | June 2 | 7 |
| Mar. 26 | 1 | Apr. 18 | 12 | May 11 | 32 | June 3 | 6 |
| Mar. 27 | 0 | Apr. 19 | 11 | May 12 | 23 | June 4 | 6 |
| Mar. 28 | 0 | Apr. 20 | 33 | May 13 | 20 | June 5 | 0 |
| Mar. 29 | 0 | Apr. 21 | 26 | May 14 | 18 | June 6 | 2 |
| Mar. 30 | 0 | Apr. 22 | 11 | May 15 | 21 | June 7 | 3 |
| Mar. 31 | 0 | Apr. 23 | 28 | May 16 | 33 | June 8 | 4 |
| Apr. 1 | 2 | Apr. 24 | 8 | May 17 | 15 | June 9 | 4 |
| Apr. 2 | 0 | Apr. 25 | 10 | May 18 | 15 | June 10 | 2 |
| Apr. 3 | 0 | Apr. 26 | 3 | May 19 | 12 | June 11 | 2 |
| Apr. 4 | 1 | Apr. 27 | 1 | May 20 | 32 | June 12 | 1 |
| Apr. 5 | 1 | Apr. 28 | 10 | May 21 | 40 | June 13 | 2 |
| Apr. 6 | 3 | Apr. 29 | 30 | May 22 | 17 | June 14 | 0 |
| Apr. 7 | 1 | Apr. 30 | 4 | May 23 | 24 | June 15 | 1 |
| Apr. 8 | 1 | May 1 | 10 | May 24 | 1 | June 16 | 0 |
| Apr. 9 | 0 | May 2 | 22 | May 25 | 5 | June 17 | 1 |
| Apr. 10 | 0 | May 3 | 7 | May 26 | 15 | June 18 | 0 |
| Apr. 11 | 2 | May 4 | 20 | May 27 | 2 | June 19 | 0 |
| Apr. 12 | 2 | May 5 | 6 | May 28 | 2 | June 20 | 1 |
| Apr. 13 | 0 | May 6 | 15 | May 29 | 9 | | |
| Apr. 14 | 5 | May 7 | 6 | May 30 | 9 | | |
| Apr. 15 | 13 | May 8 | 11 | May 31 | 8 | | |

The rise in temperature on March 27 seems to have started a few moths to emergence while the later rise on April 13 brought out a large number of adults, and it was at this time that the first absolute maximum occurred. From this time on to May 20 the temperature remained little changed, but on that date it rose and seemingly occasioned the second absolute maximum emergence, which occurred the next day. By May 28 emergence was on the wane and the temperature had little or nothing to do with emergence following. The majority of moths issued between April 20 and May 23, a maximum period of 33 days. The total period extended from March 24 to June 20, or 89 days.

*Time of emergence of moths in the spring versus the time wintering larvæ leave the fruit the year before.*—Larvæ were collected from beneath burlap bands weekly from June 6 to August 22, 1910, and each weekly lot was assigned to a separate jar. Records were then kept of the moths emerging from these jars for first-brood adults of 1910 and those which wintered over as larvæ for spring-brood moths in 1911. The material collected June 20 was, unfortunately, used for another purpose and so is excluded in these records. Table XXXIII indicates the daily emergence from each jar and the dates when collections were made. The percentages of adults issuing from each jar in 1910 and 1911 and the totals for both years are also given. It will be observed that the moths of the earlier collections mostly issued in 1910 as first-brood adults, while those of the later collections mostly wintered over to emerge as overwintering adults. Of all larvæ and pupæ collected only 53.7 per cent issued as adults. Of these the ratio of those emerging in 1910 to those emerging in 1911 was as 33 to 20, roughly speaking. Of the whole number of individuals collected 33.4 per cent issued as adults in 1910 and 20.3 per cent in 1911. The time of collection of larvæ in the summer had no influence on the time of emergence of adults the following spring.

TABLE XXXIII.—*Adult emergence of the first and second broods from band material collected in 1909.*

| Jar No. | Date of collection. | Number collected— | | Total. | Emergence— | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Larvæ. | Pupæ. | | 1910 | | 1911 | | 1910+1911 | |
| | 1910 | | | | *No.* | *Per ct.* | *No.* | *Per ct.* | *No.* | *Per ct.* |
| C- 1 | June 6 | 22 | 6 | 28 | 8 | 28 | 0 | 0 | 8 | 28 |
| C- 2 | June 13 | 22 | 1 | 77 | 32 | 41.5 | 0 | 0 | 32 | 41.5 |
| C- 4 | June 27 | 173 | 0 | 173 | 68 | 39.3 | 33 | 19.1 | 101 | 58.4 |
| C- 5 | July 4 | 114 | 3 | 117 | 45 | 38.5 | 34 | 29 | 79 | 67.5 |
| C- 6 | July 11 | 326 | 28 | 354 | 123 | 34.7 | 78 | 22 | 201 | 56.7 |
| C- 7 | July 18 | 203 | 13 | 216 | 80 | 37 | 32 | 14.8 | 112 | 51.8 |
| C- 8 | July 25 | 102 | 9 | 111 | 23 | 20.7 | 22 | 19.8 | 45 | 40.5 |
| C- 9 | Aug. 1 | 41 | 5 | 46 | 12 | 26.1 | 16 | 34.7 | 28 | 60.8 |
| C-10 | Aug. 8 | 18 | 1 | 19 | 0 | 0 | 7 | 36.8 | 7 | 36.8 |
| C-11 | Aug. 15 | 13 | 5 | 18 | 2 | 11.1 | 7 | 38.9 | 9 | 50 |
| C-12 | Aug. 27 | 20 | 0 | 20 | 1 | 5 | 10 | 50 | 11 | 55 |
| | Total. | 1,108 | 71 | 1,179 | 394 | 33.4 | 239 | 20.3 | 633 | 53.7 |

*Time during the day when moths emerged.*—Observations on 100 moths were taken to determine what time of the day emergence was most common. Jars in which pupæ for emergence were kept were examined four times a day for 14 days. The times of examination were 9 a. m., 11 a. m., 1 p. m., and 4 p. m. Out of the 100 moths only 9 issued between 4 p. m. and 9 a. m., 44 emerged between 9 a. m. and 11 a. m., 42 between 11 a. m. and 1 p. m., and the remaining 5 between 1 p. m. and 4 p. m. Thus it seems that from 9 a. m. until 1 p. m. is the customary time of emergence. (See Table XXXIV.)

TABLE XXXIV.—*Spring brood of moths. Time during the day when moths emerged.*

| Date. | Number emerging before— | | | | Total emergence. |
|---|---|---|---|---|---|
| | 9 a. m. | 11 a. m. | 1 p. m. | 4 p. m. | |
| Apr. 26... | 2 | 0 | 0 | 0 | 2 |
| Apr. 28... | 0 | 1 | 3 | 3 | 7 |
| Apr. 29... | 1 | 11 | 12 | 0 | 24 |
| May 1.... | 2 | 3 | 0 | 0 | 5 |
| May 2.... | 0 | 12 | 5 | 1 | 18 |
| May 3.... | 1 | 4 | 1 | 0 | 6 |
| May 4.... | 0 | 6 | 4 | 0 | 10 |
| May 6.... | 0 | 0 | 6 | 0 | 6 |
| May 8.... | 1 | 0 | 2 | 0 | 3 |
| May 9.... | 1 | 1 | 2 | 0 | 4 |
| May 10... | 1 | 3 | 2 | 0 | 6 |
| May 11... | 0 | 3 | 3 | 0 | 6 |
| May 12... | 0 | 0 | 1 | 1 | 1 |
| May 15... | 0 | 0 | 1 | 0 | 1 |
| Total.. | 9 | 44 | 42 | 5 | 100 |

*Period of oviposition.*—Although moths were placed in an oviposition cage with apples as soon as they emerged, no eggs were observed until June 1. After that time there was no difficulty in obtaining eggs. In the field eggs occurred early in April. No eggs could be obtained from single pairs of spring-brood moths, and thus no data were obtained as to the number of eggs a single female could deposit. In April and May, 1911, the mean temperature was considerably below normal and possibly this fact may account for the moths refusing to oviposit on the apples. From June 2 to 9 maximum oviposition took place.

*Longevity of spring brood of moths.*—Records were kept relative to the length of life of 40 moths which were placed in two jars and which were fed on grape juice and brown sugar. The results of these observations are given in Table XXXV and the summary of the results in Table XXXVI.

TABLE XXXV.—*Spring brood of moths, 1911. Length of life of the moths.*

| Cage A. | | | | Cage B. | | | |
|---|---|---|---|---|---|---|---|
| Number of moths. | Date of— | | Days. | Number of moths. | Date of— | | Days. |
| | Emergence. | Death. | | | Emergence. | Death. | |
| 2 | Apr. 29.... | May 1..... | 2 | 1 | May 3..... | May 4..... | 1 |
| 1 | .....do..... | May 2..... | 3 | 2 | .....do..... | May 5..... | 2 |
| 3 | .....do..... | May 3..... | 4 | 1 | .....do..... | May 7..... | 4 |
| 1 | .....do..... | May 4..... | 5 | 3 | .....do..... | May 10.... | 7 |
| 1 | .....do..... | May 5..... | 6 | 4 | .....do..... | May 12.... | 9 |
| 1 | .....do..... | May 7..... | 8 | 5 | .....do..... | May 13.... | 10 |
| 1 | .....do..... | May 8..... | 9 | 1 | .....do..... | May 14.... | 11 |
| 1 | .....do..... | May 9..... | 10 | 17 | | | 44 |
| 4 | .....do..... | May 12.... | 13 | | | | |
| 1 | .....do..... | May 13.... | 14 | | | | |
| 2 | .....do..... | May 14.... | 15 | | | | |
| 2 | .....do..... | May 16.... | 17 | | | | |
| 3 | .....do..... | May 17.... | 18 | | | | |
| 23 | | | 124 | | | | |

The average length of life of the moths in cage A was 10.5 days, while that of those in cage B was 7.41 days. The combined average was thus 9.19 days.

TABLE XXXVI.—*Longevity of moths of spring brood. Summary of Table XXXV.*

| Observations. | Days. |
|---|---|
| Average | 9.19 |
| Maximum | 18 |
| Minimum | 1 |

## FIRST GENERATION.

### FIRST BROOD OF EGGS.

*Incubation period.*—In the preceding pages the length of the period of egg deposition was considered under the habits of the moth.

A record of the length of the egg stage for 34 eggs is shown in Table XXXVII. As mentioned before, the earliest emerging moths would not oviposit in the cages, and it is probable that all eggs deposited previous to June 1 required from 15 to 18 days for the egg stage.

TABLE XXXVII.—*First-brood eggs. Incubation period of eggs laid in the rearing cages.*

| No. of apple. | Number of eggs. | Date of deposition. | Red ring. | | Black spot. | | Hatched. | | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date. | Number of eggs. | |
| | | | | | | | | | *Days.* |
| 1 | 1 | June 1 | June 7 | 1 | June 14 | 1 | June 16 | 1 | 15 |
| 2 | 3 | June 2 | June 5 | 3 | June 15 | 3 | June 17 | 3 | 15 |
| 3 | 4 | ...do..... | June 6 | 4 | ...do..... | 4 | ...do..... | 4 | 15 |
| 4 | 3 | ...do..... | ..do.....<br>June 8 | 2<br>1 | ...do.....<br>June 16 | 2<br>1 | ..do .... | 3 | 15 |
| 5 | 5 | June 4 | June 7 | 5 | June 15<br>June 16 | 4<br>1 | June 18 | 5 | 14 |
| 6 | 4 | June 5 | June 8 | 4 | June 17 | 4 | ...do..... | 4 | 13 |
| 7 | 2 | ...do..... | ..do.....<br>June 9 | 1<br>1 | June 18 | 2 | June 19 | 2 | 14 |
| 8 | 2 | June 8 | June 10<br>June 11 | 1<br>1 | ..do..... | 2 | ...do..... | 2 | 11 |
| 9 | 4 | ...do..... | ...do..... | 4 | ...do..... | 4 | ...do..... | 4 | 11 |
| 10 | 2 | ...do..... | June 12 | 2 | ...do..... | 2 | ...do..... | 2 | 11 |
| 11 | 3 | June 9 | June 11<br>June 12 | 1<br>2 | ..do..... | 3 | ...do..... | 3 | 10 |
| 12 | 1 | June 10 | ...do..... | 1 | June 19 | 1 | June 20 | 1 | 10 |
| 13 | 1 | June 11 | June 13 | 1 | June 20 | 1 | June 23 | 1 | 12 |
| 14 | 1 | June 12 | ...do..... | 1 | ...do..... | 1 | ...do..... | 1 | 11 |
| 15 | 8 | June 16 | June 18 | 8 | June 26 | 8 | June 28 | 8 | 12 |

Table XXXVIII shows a summary of Table XXXVII.

TABLE XXXVIII.—*Incubation period of first-brood eggs. Summary of Table XXXVII.*

| Observations. | Days of incubation. |
|---|---|
| Average | 12.77 |
| Maximum | 15 |
| Minimum | 10 |

From Table XXXVIII it is seen that the maximum egg stage was 15 days, the minimum 10, and the average 12.77 days. The average time before appearance of the red ring was 3 days, and the time before appearance of the black spot 11 days.

### FIRST BROOD OF LARVÆ.

*Time of hatching.*—The first larva to appear from eggs laid by captive moths hatched June 16. In the field at this time some full-sized larvæ were noticed, which were in all probability just-hatched larvæ about May 1, but, as has been stated before, the captive moths refused to deposit eggs before June 1. From eggs laid after this date 16 larvæ hatched and were placed on apples to get data on the feeding period and post-larval stage. Only six of these transformed into the pupæ and Table XXXIX records their larval history.

TABLE XXXIX.—*First-brood larvæ: Feeding period and length of the post-larval stage.*

| No. of larva. | Sex. | Date when— | | | | Length of larval stage. |
|---|---|---|---|---|---|---|
| | | Larva hatched. | Larva entered apple. | Larva left apple. | Larva pupated. | |
| | | | | | | *Days.* |
| 1 | ♂ | June 17 | June 17 | July 12 | July 13 | 26 |
| 2 | ♀ | June 19 | June 19 | July 17 | July 26 | 37 |
| 3 | ♂ | ...do.... | ...do.... | July —[a] | July 23 | 34 |
| 4 | ♀ | ...do.... | ...do.... | July 13 | July 31 | 42 |
| 5 | ♂ | June 20 | June 20 | July 17 | July 27 | 37 |
| 6 | ? | June 28 | June 28 | July 23 | July 30 | 32 |

[a] Larva spun cocoon in apple.

The average length of the total larval stage was 34.67 days, including the time taken by the larva to spin its cocoon after leaving the apple, which is the post-larval stage. As this period varies considerably, in the above six instances from 1 to 18 days, the true larval stage or feeding period is found by simply taking the time of larval existence until the worm leaves the apple. In the instance of larva No. 3 the cocoon was spun inside the apple, so the time spent in feeding could not be determined. The average time taken by the other five to attain full growth was 25.8 days, with a maximum of 28 and a minimum of 24 days.

*Number of larvæ developing in each apple.*—Several larvæ entered the same apple in numerous instances, but never more than two developed. In the orchard usually but one larva is found in each apple, although the entrance holes of several often can be observed. An apple from which a larva of the first generation has issued may later contain a larva of the succeeding generation.

### FIRST BROOD OF PUPÆ.

*Time of pupation and length of pupal stage.*—The larvæ for this record were collected from banded trees and placed in gelatin capsules and vials to obtain pupation records. Practically no difference in length of pupal period was found in those kept in capsules and in those in vials. Of the 123 larvæ placed for pupation 52 died, and of the 71 remaining 12 elected to pass the winter as larvæ. The pupation record in Table XL is therefore recorded from only 59 individuals. The earliest pupa occurred July 8, the latest August 16; the earliest adult issued July 27, the latest September 13. Consequently the pupal period ranged from July 8 to September 13, a period of 68 days. The shortest pupal stage was 18 days, the longest 37, and the average 23.12 days. Using this average we find that probably the earliest pupa occurred July 4, and as the latest adult (see adult emergence record, Table XLIII) issued September 29 we have a theoretical range for the pupal period of 87 days.

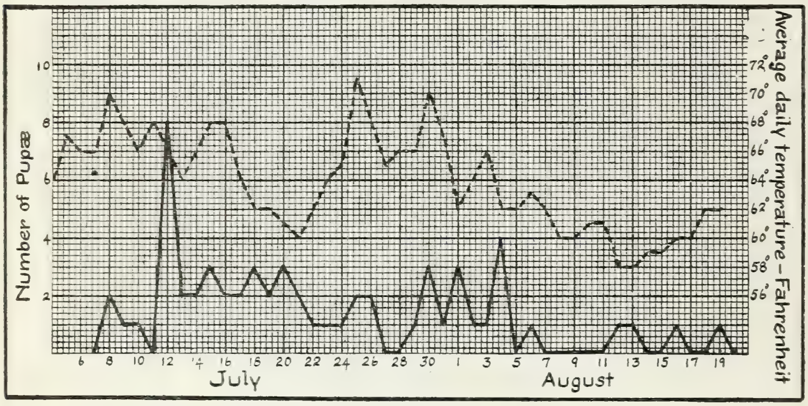

FIG. 34.—Diagram showing first-brood pupæ, 1911. (Original.)

Of the larvæ under observation there were 21 males and 33 females, the average pupal stage of the former being 22.95 days and that of the latter 23.45 (see Table XLI), the females thus requiring half a day longer to develop into adults. Five individuals escaped before their sex could be determined.

Figure 34 shows graphically the time of pupation of the first brood.

TABLE XL.—*First-brood pupæ: Length of the pupal period from material collected in 1911 on banded trees.*

| No. of individual. | Date of— | | Sex of moth. | Length of pupal period. | No. of individual. | Date of— | | Sex of moth. | Length of pupal period. |
|---|---|---|---|---|---|---|---|---|---|
| | Pupation. | Emergence. | | | | Pupation. | Emergence. | | |
| | | | | *Days.* | | | | | *Days.* |
| 1 | July 8 | July 27 | ♀ | 19 | 31 | July 20 | Aug. 13 | ...... | 24 |
| 2 | ...do.... | ...do.... | ♀ | 19 | 32 | July 21 | Aug. 11 | ♀ | 21 |
| 3 | July 9 | ...do.... | ♀ | 18 | 33 | ...do.... | Aug. 12 | ♀ | 22 |
| 4 | July 10 | July 31 | ♀ | 21 | 34 | July 22 | Aug. 17 | ♂ | 26 |
| 5 | July 12 | ...do.... | ♀ | 19 | 35 | July 24 | Aug. 14 | ...... | 21 |
| 6 | ...do.... | Aug. 1 | ♂ | 20 | 36 | July 25 | Aug. 17 | ♂ | 23 |
| 7 | ...do.... | ...do.... | ♂ | 20 | 37 | ...do.... | ...do.... | ♀ | 23 |
| 8 | ...do.... | ...do.... | ♀ | 20 | 38 | July 26 | Aug. 19 | ♀ | 24 |
| 9 | ...do.... | ...do.... | ♀ | 20 | 39 | ...do.... | Aug. 20 | ♀ | 25 |
| 10 | ...do.... | Aug. 2 | ...... | 21 | 40 | July 29 | Aug. 21 | ♀ | 23 |
| 11 | ...do.... | Aug. 3 | ♀ | 22 | 41 | July 30 | Aug. 23 | ♀ | 24 |
| 12 | ...do.... | Aug. 6 | ♀ | 25 | 42 | ...do.... | ...do.... | ♂ | 24 |
| 13 | July 13 | Aug. 1 | ♂ | 19 | 43 | ...do.... | Aug. 28 | ♂ | 29 |
| 14 | ...do.... | Aug. 3 | ♂ | 21 | 44 | July 31 | Aug. 24 | ♀ | 24 |
| 15 | July 14 | ...do.... | ♂ | 20 | 45 | Aug. 1 | Aug. 26 | ♀ | 25 |
| 16 | ...do.... | ...do.... | ♂ | 20 | 46 | ...do.... | Aug. 27 | ♀ | 26 |
| 17 | July 15 | ...do.... | ...... | 19 | 47 | ...do.... | ...do.... | ♀ | 26 |
| 18 | ...do.... | Aug. 5 | ♂ | 21 | 48 | Aug. 2 | Aug 26 | ♀ | 24 |
| 19 | ...do.... | Aug. 7 | ...... | 23 | 49 | Aug. 3 | Aug. 30 | ♀ | 27 |
| 20 | July 16 | Aug. 6 | ♂ | 21 | 50 | ...do.... | Sept. 9 | ♀ | 37 |
| 21 | ...do.... | Aug. 19 | ♂ | 34 | 51 | Aug. 4 | Aug. 28 | ♀ | 24 |
| 22 | July 17 | Aug. 5 | ♀ | 19 | 52 | ...do.... | Aug. 29 | ♂ | 25 |
| 23 | ...do.... | Aug. 7 | ♀ | 21 | 53 | ...do.... | ...do.... | ♀ | 25 |
| 24 | July 18 | Aug. 8 | ♂ | 21 | 54 | ...do.... | Aug. 31 | ♀ | 27 |
| 25 | ...do.... | Aug. 9 | ♂ | 22 | 55 | Aug. 6 | Sept. 2 | ♀ | 27 |
| 26 | ...do.... | Aug. 8 | ♀ | 22 | 56 | Aug. 12 | Sept. 7 | ♂ | 26 |
| 27 | July 19 | Aug. 9 | ♀ | 21 | 57 | Aug. 13 | Sept. 2 | ♂ | 20 |
| 28 | ...do.... | Aug. 14 | ♀ | 26 | 58 | Aug. 16 | Sept. 13 | ♀ | 28 |
| 29 | July 20 | Aug. 11 | ♂ | 22 | 59 | Aug. 19 | ...do.... | ♂ | 25 |
| 30 | ...do.... | Aug. 12 | ♂ | 23 | | | | | |

The variations in the length of the pupal stage are shown in Table XLI and a summary of Table XL in Table XLII.

TABLE XLI.—*First-brood pupæ: Variations in the length of the pupal period for 59 individuals.*

| Pupæ. | Days. | Pupæ. | Days. |
|---|---|---|---|
| 1 | 18 | 6 | 25 |
| 6 | 19 | 5 | 26 |
| 7 | 20 | 3 | 27 |
| 10 | 21 | 1 | 28 |
| 5 | 22 | 1 | 29 |
| 5 | 23 | 1 | 34 |
| 7 | 24 | 1 | 37 |

TABLE XLII.—*First-brood pupæ: Summary of Table XL.*

| Observations. | Days in the pupal stage. |
|---|---|
| Average.......... | 23.12 |
| Maximum....... | 37 |
| Minimum........ | 18 |

### FIRST BROOD OF MOTHS.

*Time of emergence.*—On July 22 the first moths emerged from band material collected July 6. The emergence reached its maximum August 19 and continued on until September 29. Most of the moths, however, emerged in August and the first few days in September. As can be seen from figure 35 and Table XLIII the emergence is drawn out so that it covers a period of 70 days:

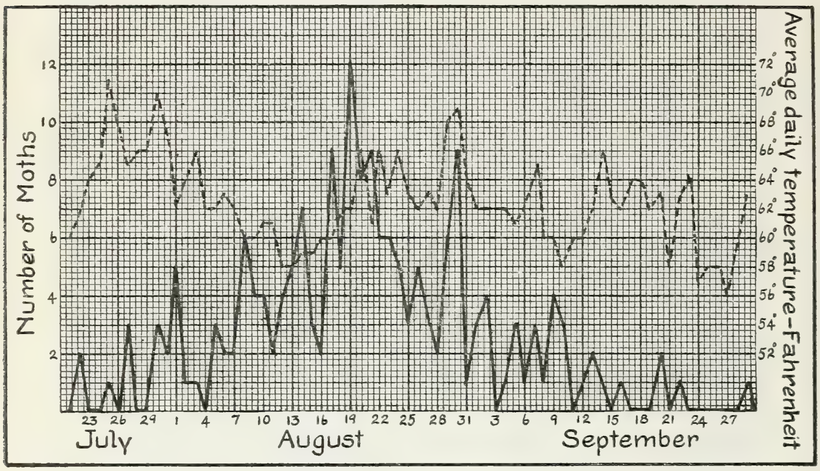

FIG. 35.—Diagram showing emergence of first-brood moths, 1911. (Original.)

TABLE XLIII.—*Emergence of moths of the first brood: Material from banded trees.*

| Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. | Date of emergence. | Number of moths. |
|---|---|---|---|---|---|---|---|
| July 22 | 2 | Aug. 11 | 2 | Aug. 25 | 3 | Sept 9 | 4 |
| July 25 | 1 | Aug. 12 | 4 | Aug. 26 | 5 | Sept. 10 | 3 |
| July 27 | 3 | Aug. 13 | 5 | Aug. 27 | 3 | Sept. 12 | 1 |
| July 30 | 3 | Aug. 14 | 7 | Aug. 28 | 2 | Sept. 13 | 2 |
| July 31 | 2 | Aug. 15 | 3 | Aug. 29 | 6 | Sept. 14 | 1 |
| Aug. 1 | 5 | Aug. 16 | 2 | Aug. 30 | 9 | Sept. 16 | 1 |
| Aug. 2 | 1 | Aug. 17 | 9 | Aug. 31 | 1 | Sept. 20 | 2 |
| Aug. 3 | 1 | Aug. 18 | 5 | Sept. 1 | 3 | Sept. 22 | 1 |
| Aug. 5 | 3 | Aug. 19 | 12 | Sept. 2 | 4 | Sept. 29 | 1 |
| Aug. 6 | 2 | Aug. 20 | 8 | Sept. 4 | 1 | | |
| Aug. 7 | 2 | Aug. 21 | 9 | Sept. 5 | 3 | | 157 |
| Aug. 8 | 6 | Aug. 22 | 6 | Sept. 6 | 1 | | |
| Aug. 9 | 4 | Aug. 23 | 6 | Sept. 7 | 3 | | |
| Aug. 10 | 4 | Aug. 24 | 5 | Sept. 8 | 1 | | |

*Oviposition period.*—Nearly all of the moths which emerged were utilized for securing eggs by confining them in Riley cages in which apples had been suspended on strings. The moths oviposited readily and a large number of eggs were secured. The first eggs were obtained on August 10, or 19 days after the first moths emerged, which was on July 22. The earliest moths did not oviposit in the cages but it is probable eggs were present in the field about the middle of July. The oviposition period continued throughout August and September.

### LIFE CYCLE OF FIRST GENERATION.

Along with other rearing experiments to obtain the length of the egg stage and the feeding periods of the larvæ a number of adults were reared from the egg to ascertain the complete life cycle. In this experiment only six individuals were carried through the entire period and the details of the work are shown in Table XLIV.

Table XLV is a summary of Table XLIV and shows that the average life cycle from egg to egg (allowing 3 days after the moths emerge before eggs are laid) was 71.3 days, the maximum 77 days and the minimum 67 days. Adding the average egg stage, or 12.77 days, the average feeding period, or 25.08 days, the average post-larval stage, or 9 days, the average pupal stage, or 23.12 days, and allowing 3 days for eggs to be deposited after the moths emerge, a total of 72.95 days is obtained, or very close to the average life cycle, from actual rearing experiments.

TABLE XLIV.—*Life cycle of the first generation.*

| No. of individual. | Sex. | Date of— | | | | Length of egg stage. |
|---|---|---|---|---|---|---|
| | | Deposition. | Red ring. | Black spot. | Larva hatching. | |
| | | | | | | *Days.* |
| 1 | ♂ | June 2 | June 5 | June 15 | June 17 | 15 |
| 2 | ♀ | June 8 | June 10 | June 18 | June 19 | 11 |
| 3 | ♂ | ...do.... | June 11 | ...do.... | ...do.... | 11 |
| 4 | ♀ | ...do.... | ...do.... | ...do.... | ...do.... | 11 |
| 5 | ♂ | June 10 | June 12 | June 19 | June 20 | 10 |
| 6 | ? | ...do.... | June 18 | June 26 | June 28 | 12 |

| No. of individual. | Date of— | | | Length of larval stage. | Emergence of adult. | Length of pupal stage. | Length of life cycle. Eggs to adult. | Total length of life cycle. Egg to egg. |
|---|---|---|---|---|---|---|---|---|
| | Larva entering apple. | Larva leaving apple. | Pupation. | | | | | |
| | | | | *Days.* | | *Days.* | *Days.* | *Days.* |
| 1 | June 17 | July 12 | July 13 | 26 | Aug. 5 | 23 | 64 | 67 |
| 2 | June 19 | July 17 | July 26 | 37 | Aug. 17 | 22 | 70 | 73 |
| 3 | ...do.... | ........... | July 23 | 34 | Aug. 13 | 21 | 66 | 69 |
| 4 | ...do.... | July 13 | July 31 | 42 | Aug. 21 | 21 | 74 | 77 |
| 5 | June 20 | July 17 | July 27 | 37 | Aug. 18 | 22 | 69 | 72 |
| 6 | June 28 | July 23 | July 30 | 32 | Aug. 22 | 23 | 67 | 70 |

TABLE XLV.—*Summary of Table XLIV.*

| Observation. | Total life cycle. Egg to adult. | Total life cycle. Egg to egg. |
|---|---|---|
| | *Days.* | *Days.* |
| Average | 68.3 | 71.3 |
| Maximum | 74 | 77 |
| Minimum | 64 | 67 |

### SECOND GENERATION.

#### SECOND BROOD OF EGGS.

*Incubation period.*—In all, 845 eggs were deposited during the 33 days on apples in the cages used for this purpose. No record was kept as to how many eggs a single female deposited, but, judging from the number of female moths confined and the eggs deposited by them, the average for each female must have been about 40. No record was kept as to the time of day the females selected for oviposition, but observation throughout the day showed moths ovipositing from early in the morning until evening. Table XLVI shows the length of the egg stage for 760 individuals.

TABLE XLVI.—*Second-brood eggs. Incubation period of eggs laid in the rearing cages.*

| No. of apple. | Number of eggs. | Date of deposition. | Red ring. | | Black spot. | | Hatched. | | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | |
| | | | | | | | | | *Days.* |
| 1 | 3 | Aug. 10 | .......... | ........ | Aug. 21 | 3 | Aug. 23 | 3 | 13 |
| 2 | 9 | Aug. 16 | Aug. 19 | 9 | Aug. 25<br>Aug. 26 | 8<br>1 | Aug. 27<br>Aug. 28<br>Aug. 29 | 1<br>6<br>1 | 11<br>12<br>13 |
| 4 | 46 | Aug. 17 | Aug. 20<br>Aug. 21 | 30<br>4 | ..do.....<br>Aug. 27<br>Aug. 28 | 39<br>3<br>3 | Aug. 28<br>Aug. 29<br>Aug. 30<br>Aug. 31<br>Sept. 1 | 6<br>23<br>9<br>2<br>1 | 11<br>12<br>13<br>14<br>15 |
| 5 | 8 | ...do..... | Aug. 20<br>Aug. 21 | 6<br>1 | Aug. 26<br>Aug. 27 | 6<br>1 | Aug. 29 | 6 | 12 |
| 6 | 4 | ...do..... | Aug. 20 | 2 | Aug. 26<br>Aug. 27 | 3<br>1 | ..do..... | 3 | 12 |
| 8 | 14 | Aug. 18 | ..do.....<br>Aug. 21<br>Aug. 22 | 4<br>5<br>1 | Aug. 28 | 10 | Aug. 30<br>Aug. 31 | 3<br>4 | 12<br>13 |
| 9 | 2 | ...do..... | Aug. 21 | 1 | Aug. 27 | 1 | Aug. 29 | 1 | 11 |
| 10 | 1 | ...do..... | ...do..... | 1 | Aug. 28 | 1 | Aug. 30 | 1 | 12 |
| 11 | 25 | Aug. 28 | Aug. 20<br>Aug. 21 | 5<br>16 | Aug. 27<br>Aug. 28 | 6<br>19 | Aug. 29<br>Aug. 30<br>Aug. 31<br>Sept. 1 | 5<br>15<br>2<br>1 | 11<br>12<br>13<br>14 |
| 12 | 2 | Aug. 18 | ...do..... | 2 | ...do..... | 2 | Aug. 30 | 2 | 12 |
| 13 | 4 | Aug. 19 | Aug. 22 | 2 | Aug. 29<br>Aug. 30 | 1<br>2 | Aug. 31<br>Sept. 1<br>Sept. 2 | 1<br>1<br>1 | 12<br>13<br>14 |
| 14 | 9 | ...do..... | Aug. 21 | 6 | Aug. 28 | 9 | Aug. 30<br>Aug. 31 | 3<br>6 | 11<br>12 |
| 15 | 3 | ...do..... | ..do.....<br>Aug. 22 | 1<br>1 | ...do.....<br>Aug. 29 | 2<br>1 | Aug. 30<br>Aug. 31 | 1<br>2 | 11<br>12 |
| 16 | 6 | ...do..... | Aug. 21<br>Aug. 22 | 1<br>3 | Aug. 28 | 5 | Aug. 30<br>Aug. 31<br>Sept. 1<br>Sept. 2 | 1<br>2<br>1<br>1 | 11<br>12<br>13<br>14 |
| 17 | 4 | ...do..... | .......... | ........ | Aug. 29<br>Aug. 30 | 2<br>1 | Sept. 1<br>Sept. 2 | 1<br>1 | 13<br>14 |
| 18 | 4 | Aug. 20 | Aug. 22<br>Aug. 23 | 3<br>1 | ..do..... | 4 | Sept. 1 | 4 | 12 |
| 19 | 11 | ...do..... | Aug. 22<br>Aug. 23 | 6<br>2 | Aug. 29<br>Aug. 30 | 5<br>5 | Aug. 31<br>Sept. 1<br>Sept. 2 | 1<br>8<br>1 | 11<br>12<br>13 |
| 20 | 11 | ...do..... | Aug. 22 | 9 | Aug. 29<br>Aug. 30 | 3<br>4 | Aug. 31<br>Sept. 1 | 1<br>8 | 11<br>12 |
| 21 | 15 | ...do..... | ..do.....<br>Aug. 23 | 14<br>1 | Aug. 29<br>Aug. 30 | 11<br>4 | Aug. 31<br>Sept. 1 | 2<br>12 | 11<br>12 |
| 22 | 2 | ...do..... | ...do..... | 2 | Aug. 29 | 2 | ..do.....<br>Sept. 2 | 1<br>1 | 12<br>13 |
| 23 | 3 | Aug. 21 | Aug. 24 | 2 | Aug. 31 | 3 | Sept. 1<br>Sept. 2 | 1<br>1 | 11<br>12 |
| 24 | 20 | ...do..... | Aug. 23<br>Aug. 24 | 2<br>14 | ..do..... | 18 | Sept. 1<br>Sept. 2 | 6<br>9 | 11<br>12 |
| 25 | 16 | ...do..... | Aug. 23<br>Aug. 24 | 1<br>11 | ..do..... | 16 | Sept. 1<br>Sept. 2 | 5<br>6 | 11<br>12 |

TABLE XLVI.—*Second-brood eggs. Incubation period of eggs laid in the rearing cages*—Continued.

| No. of apple. | Number of eggs. | Date of deposition. | Red ring. | | Black spot. | | Hatched. | | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | |
| | | | | | | | | | *Days.* |
| 26 | 7 | Aug. 21 | Aug. 24 | 4 | Aug. 31 | 6 | Sept. 1<br>Sept. 2<br>Sept. 4 | 1<br>3<br>1 | 11<br>12<br>14 |
| 28 | 12 | ...do..... | ..do.....<br>Aug. 25 | 9<br>3 | ..do..... | 12 | Sept. 1<br>Sept. 2<br>Sept. 3 | 4<br>7<br>1 | 11<br>12<br>13 |
| 29 | 20 | ...do..... | Aug. 24<br>Aug. 25 | 8<br>7 | ..do..... | 18 | Sept. 1<br>Sept. 2 | 3<br>15 | 11<br>12 |
| 30 | 25 | Aug. 22 | ...do..... | 15 | ..do.....<br>Sept. 1 | 4<br>20 | ..do.....<br>Sept. 3<br>Sept. 4 | 1<br>22<br>1 | 11<br>12<br>13 |
| 31 | 6 | ...do..... | ...do..... | 6 | Aug. 31<br>Sept. 1 | 1<br>5 | Sept. 3 | 6 | 12 |
| 32 | 3 | ...do..... | ...do..... | 3 | Aug. 31<br>Sept. 1 | 1<br>2 | Sept. 2<br>Sept. 3 | 1<br>2 | 11<br>12 |
| 33 | 13 | ...do..... | ..do.....<br>Aug. 26 | 5<br>2 | Aug. 31<br>Sept. 1 | 7<br>5 | Sept. 2<br>Sept. 3<br>Sept. 5 | 5<br>6<br>1 | 11<br>12<br>14 |
| 34 | 8 | ...do..... | Aug. 25 | 7 | Aug. 31<br>Sept. 1 | 1<br>7 | Sept. 2<br>Sept. 3 | 1<br>7 | 11<br>12 |
| 35 | 24 | ...do..... | ..do.....<br>Aug. 26 | 3<br>3 | Aug. 31<br>Sept. 1 | 20<br>4 | Sept. 2<br>Sept. 3 | 11<br>13 | 11<br>12 |
| 36 | 5 | Aug. 23 | ...do..... | 3 | Sept. 1<br>Sept. 2 | 1<br>4 | ..do..... | 5 | 11 |
| 37 | 4 | ...do..... | ...do..... | 2 | ...do..... | 4 | Sept. 4 | 4 | 12 |
| 38 | 7 | ...do..... | ..do.....<br>Aug. 28 | 1<br>1 | ..do..... | 7 | ..do.....<br>Sept. 5<br>Sept. 6 | 2<br>4<br>1 | 12<br>13<br>14 |
| 39 | 11 | ...do..... | Aug. 26<br>Aug. 28 | 4<br>1 | ...do.....<br>Sept. 3 | 5<br>1 | Sept. 4<br>Sept. 5 | 3<br>3 | 12<br>13 |
| 40 | 14 | ...do..... | Aug. 26 | 9 | Sept. 2 | 14 | Sept. 4 | 14 | 12 |
| 41 | 6 | ...do.... | ..do.....<br>Aug. 28 | 4<br>2 | ..do.....<br>Sept. 3<br>Sept. 4 | 4<br>1<br>1 | ...do.....<br>Sept. 5<br>Sept. 6 | 3<br>2<br>1 | 12<br>13<br>14 |
| 42 | 27 | ...do..... | Aug. 26<br>Aug. 28 | 16<br>4 | Sept. 2<br>Sept. 3 | 25<br>2 | Sept. 4<br>Sept. 5 | 18<br>7 | 12<br>13 |
| 43 | 29 | Aug. 24 | Aug. 27<br>Aug. 28 | 16<br>7 | ...do.....<br>Sept. 5 | 26<br>3 | ..do.....<br>Sept. 6<br>Sept. 8 | 7<br>21<br>1 | 12<br>13<br>15 |
| 44 | 19 | ...do..... | Aug. 27 | 18 | Sept. 3<br>Sept. 4<br>Sept. 5 | 17<br>1<br>1 | Sept. 5<br>Sept. 6<br>Sept. 7 | 9<br>8<br>2 | 12<br>13<br>14 |
| 45 | 25 | ...do..... | ...do..... | 19 | Sept. 3<br>Sept. 4 | 23<br>2 | Sept. 5<br>Sept. 6<br>Sept. 7 | 14<br>8<br>2 | 12<br>13<br>14 |
| 46 | 10 | ...do..... | ...do..... | 6 | Sept. 3 | 10 | Sept. 5<br>Sept. 6 | 7<br>3 | 12<br>13 |
| 47 | 20 | ...do..... | ...do..... | 17 | ...do..... | 20 | Sept. 5<br>Sept. 6 | 8<br>12 | 12<br>13 |
| 48 | 40 | Aug. 25 | Aug. 28 | 27 | Sept. 4<br>Sept. 5 | 33<br>4 | Sept. 7<br>Sept. 8 | 34<br>2 | 13<br>14 |
| 49 | 36 | ...do..... | ...do..... | 29 | Sept. 4<br>Sept. 5 | 33<br>3 | Sept. 7<br>Sept. 8 | 33<br>2 | 13<br>14 |
| 50 | 21 | ...do..... | ...do..... | 18 | Sept. 4 | 21 | Sept. 7<br>Sept. 8 | 20<br>1 | 13<br>14 |
| 51 | 4 | ...do..... | ...do..... | 3 | ...do..... | 3 | Sept. 7 | 3 | 13 |
| 52 | 3 | ...do..... | ...do..... | 1 | Sept. 4<br>Sept. 7 | 2<br>1 | Sept. 5<br>Sept. 7 | 1<br>1 | 11<br>13 |
| 53 | 15 | Aug. 26 | Aug. 30 | 9 | Sept. 5<br>Sept. 6 | 3<br>12 | Sept. 8<br>Sept. 9 | 13<br>2 | 13<br>14 |
| 54 | 4 | ...do..... | ...do..... | 3 | Sept. 7 | 3 | Sept. 8 | 3 | 13 |
| 55 | 23 | ...do..... | ...do..... | 20 | Sept. 5<br>Sept. 6 | 9<br>14 | ..do..... | 22 | 13 |
| 56 | 17 | ...do..... | ...do..... | 11 | Sept. 5<br>Sept. 6<br>Sept. 7 | 9<br>7<br>1 | ..do..... | 16 | 13 |
| 57 | 9 | ...do..... | ...do..... | 7 | Sept. 5<br>Sept. 6<br>Sept. 7 | 3<br>5<br>1 | ..do.....<br>Sept. 9 | 8<br>1 | 13<br>14 |
| 58 | 20 | ...do..... | ...do..... | 16 | Sept. 5<br>Sept. 6 | 4<br>15 | Sept. 8 | 19 | 13 |
| 59 | 17 | Aug. 27 | Aug. 31 | 11 | ..do.....<br>Sept. 7 | 7<br>8 | Sept. 7<br>Sept. 8<br>Sept. 9<br>Sept. 10 | 1<br>6<br>8<br>2 | 11<br>12<br>13<br>14 |

Table XLVI.—*Second-brood eggs. Incubation period of eggs laid in the rearing cages*—Continued.

| No. of apple. | Number of eggs. | Date of deposition. | Red ring. |  | Black spot. |  | Hatched. |  | Length of egg stage. |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. | Date of appearance. | Number of eggs. |  |
|  |  |  |  |  |  |  |  |  | *Days.* |
| 60 | 9 | Aug. 27 | Aug. 31 | 8 | Sept. 6<br>Sept. 7<br>Sept. 8 | 2<br>6<br>1 | Sept. 8<br>Sept. 9<br>Sept. 10 | 3<br>5<br>1 | 12<br>13<br>14 |
| 61 | 2 | ...do..... | ...do..... | 1 | Sept. 7 | 1 | Sept. 9 | 1 | 13 |
| 62 | 2 | ...do..... | ...do..... | 2 | Sept. 6 | 2 | Sept. 8 | 2 | 12 |
| 63 | 7 | Aug. 28 | Sept. 1 | 5 | Sept. 8<br>Sept. 9<br>Sept. 11 | 4<br>2<br>1 | Sept. 11<br>Sept. 12 | 6<br>1 | 14<br>15 |
| 64 | 7 | ...do..... | ...do..... | 6 | Sept. 8<br>Sept. 9 | 5<br>2 | Sept. 10<br>Sept. 11<br>Sept. 12 | 1<br>4<br>2 | 13<br>14<br>15 |
| 65 | 5 | ...do..... | ...do..... | 5 | Sept. 7<br>Sept. 8<br>Sept. 9 | 1<br>3<br>1 | Sept. 9<br>Sept. 10 | 1<br>4 | 12<br>13 |
| 66 | 8 | ...do..... | ...do..... | 8 | Sept. 7<br>Sept. 8 | 5<br>3 | ..do..... | 8 | 13 |
| 67 | 2 | Aug. 29 | ...do..... | 2 | ...do..... | 2 | Sept. 11 | 2 | 13 |
| 68 | 5 | ...do..... | ...do..... | 5 | ..do.....<br>Sept. 9 | 3<br>2 | ...do.....<br>Sept. 12 | 4<br>1 | 13<br>14 |
| 69 | 3 | ...do..... | ...do..... | 3 | Sept. 8 | 3 | Sept. 11 | 3 | 13 |
| 70 | 5 | Aug. 30 | ..do.....<br>Sept. 2 | 1<br>3 | Sept. 10<br>Sept. 11<br>Sept. 12 | 2<br>2<br>1 | Sept. 13<br>Sept. 14 | 3<br>2 | 14<br>15 |
| 71 | 3 | Aug. 31 | ..do.....<br>Sept. 7 | 1<br>1 | Sept. 10<br>Sept. 12 | 1<br>1 | Sept. 13<br>Sept. 14 | 1<br>1 | 13<br>14 |
| 72 | 7 | ...do..... | Sept. 4 | 1 | ...do..... | 6 | ...do..... | 4 | 14 |
| 73 | 2 | ...do..... | .......... | ........ | ...do..... | 2 | ...do..... | 2 | 14 |
| 74 | 7 | Sept. 1 | Sept. 4<br>Sept. 7 | 3<br>3 | Sept. 13 | 7 | Sept. 15 | 7 | 14 |
| 75 | 22 | ...do..... | Sept. 4<br>Sept. 7 | 5<br>10 | ..do..... | 21 | ..do.....<br>Sept. 16 | 15<br>1 | 14<br>15 |
| 76 | 4 | Sept. 3 | ...do..... | 4 | Sept. 15 | 4 | Sept. 17 | 4 | 14 |
| 77 | 16 | Sept. 4 | ...do..... | 4 | .......... | ........ | Sept. 18 | 4 | 14 |
| 78 | 4 | Sept. 12 | .......... | ........ | Sept. 22 | 4 | Sept. 25 | 4 | 13 |

From Table XLVI it will be seen that the average egg stage was 12.5 days, the later individuals remaining in the egg slightly longer than the earlier, a phenomenon probably due to the gradual lowering of the temperature. Out of 845 eggs deposited, 760, or a fraction under 90 per cent, hatched. As can be seen from a study of Table XLVI the red ring is not a constant factor in the egg development, since it could be discovered in only 610 individuals. Mortality is about equally great before and after the appearance of the black spot. Table XLVII shows the variations in the length of the egg stage as recorded in Table XLVI.

Table XLVII.—*Second-brood eggs: Variations in the length of the egg stage as recorded in Table XLVI.*

| Number of eggs. | Days. | Number of eggs. | Days. |
|---|---|---|---|
| 68 | 11 | 8 | 15 |
| 301 | 12 |  |  |
| 307 | 13 | 760 |  |
| 76 | 14 |  |  |

Table XLVIII is a summary of Table XLVI and shows the average, maximum, and minimum length of the egg stage.

TABLE XLVIII.—*Second-brood eggs: Summary of Table XLVI.*

| Observations. | Length of the egg stage. |
|---|---|
| | *Days.* |
| Average | 12.5 |
| Maximum | 15 |
| Minimum | 11 |

SECOND BROOD OF LARVÆ.

*Time of hatching.*—Eggs obtained in the cages hatched from early August until September 25, but as the first moths did not oviposit in confinement just-hatched larvæ in numbers were probably in evidence in the field from the latter part of July until the middle of October, when most varieties of apples were picked.

*Feeding period.*—Apples on which eggs had been laid were placed in jelly glasses to obtain a record of the time taken by the larval development in the fruit. Although in most cases several larvæ entered the same fruit more than two full-grown larvæ never issued from the same fruit. The apples used were yellow Newtown Pippins and were large enough to provide food for several worms. The larvæ have a habit of coming out of the apple, wandering around the glass for a few days, and then entering the fruit again, thus extending the period of their growth. This habit may account in part for the large variation in the length of the period between hatching and the final emergence from the fruit for the purpose of spinning the wintering cocoon. The maximum time spent in the fruit was 79 days and the minimum 43, with an average of 58.15 days.

Table XLIX gives the record of the time spent in the fruit of 39 individuals.

TABLE XLIX.—*Second-brood larvæ: Time spent in the fruit.*

| No. of apple. | Larva hatched. | Larva emerged from fruit. | Days in fruit. | No. of apple. | Larva hatched. | Larva emerged from fruit. | Days in fruit. |
|---|---|---|---|---|---|---|---|
| 13 | Sept. 1 | Oct. 21 | 50 | 53 | Sept. 7 | Nov. 22 | 76 |
| 28 | Sept. 2 | Nov. 7 | 66 | 54 | Sept. 8 | Nov. 2 | 55 |
| 29 | ...do..... | Nov. 2 | 61 | 55 | ...do..... | Nov. 21 | 74 |
| 33 | Sept. 3 | Oct. 27 | 54 | 56 | ...do..... | Nov. 5 | 58 |
| 34 | ...do..... | Nov. 1 | 59 | 57 | ...do..... | Nov. 26 | 79 |
| 35 | Sept. 2 | Oct. 22 | 50 | 59 | Sept. 9 | Nov. 13 | 65 |
| 36 | Sept. 3 | Nov. 12 | 70 | 60 | Sept. 8 | Oct. 23 | 45 |
| 36 | Sept. 4 | Oct. 20 | 46 | 60 | Sept. 10 | Nov. 24 | 75 |
| 37 | Sept. 3 | Oct. 22 | 49 | 61 | Sept. 9 | Oct. 27 | 48 |
| 40 | Sept. 5 | Oct. 20 | 45 | 61 | ...do..... | Oct. 31 | 52 |
| 41 | Sept. 4 | Nov. 4 | 61 | 62 | Sept. 8 | Nov. 15 | 68 |
| 42 | Sept. 5 | ...do..... | 60 | 63 | Sept. 11 | Oct. 30 | 49 |
| 43 | Sept. 4 | Nov. 3 | 60 | 64 | ...do..... | Nov. 11 | 61 |
| 45 | Sept. 6 | Oct. 14 | 43 | 65 | Sept. 10 | Nov. 1 | 52 |
| 46 | ...do..... | Nov. 5 | 60 | 69 | Sept. 11 | Nov. 5 | 55 |
| 47 | Sept. 5 | Nov. 14 | 70 | 75 | Sept. 15 | Nov. 2 | 48 |
| 49 | Sept. 6 | Oct. 19 | 43 | 75 | ...do..... | Nov. 20 | 66 |
| 50 | Sept. 7 | Nov. 8 | 62 | 78 | ...do..... | Nov. 12 | 58 |
| 51 | ...do..... | Oct. 31 | 54 | 79 | ...do..... | Nov. 9 | 55 |
| 52 | ...do..... | Nov. 12 | 66 | | | | |

Table L, a summary of Table XLIX, shows the average maximum and minimum time spent by the second-brood larvæ in feeding.

TABLE L.—*Feeding period of second-brood larvæ: Summary of Table XLIX.*

| Observations. | Days in the fruit. |
|---|---|
| Average | 58.15 |
| Maximum | 79 |
| Minimum | 43 |

*Time of leaving the fruit for wintering.*—Table XLIX shows that the date the earliest larvæ left the fruit was October 19, but as these larvæ were not from the earliest eggs deposited and the earliest moths did not oviposit in confinement the band record will show when most of the larvæ cocooned for the winter. The band record for 1911 shows that after August 31 second-brood larvæ were undoubtedly hibernating and that they reached their maximum from September 28 to October 5. The earliest second-brood larvæ probably cocooned the latter part of August and since half-grown larvæ were found in apples on the tree as late as November 30, it is possible that the last stragglers did not cocoon until some time during December, 1911, or January, 1912.

## NATURAL ENEMIES OF THE CODLING MOTH.

*Parasitic insects.*—The egg parasite *Trichogramma pretiosa* Riley may be regarded as a factor in the control of the codling moth in the Santa Clara Valley. In 1909 eggs of the host were collected to obtain records on the parasites. A large number of the Trichogramma issued, but as there was no record of the time when the eggs were laid by the moths or parasitized by the chalcidid, the life cycle of the parasite was not determined. In 1910 the Trichogramma was very abundant, so much so that in the life-history work on the codling moth the jelly glasses in the insectary containing the eggs had to be carefully covered to keep out the parasite. In this year a record was kept relative to the life cycle of the parasite.

Table LI gives notes on the life history of eight parasites.

TABLE LI.—*Life of Trichogramma pretiosa in codling-moth eggs.*

| Date eggs laid. | Date parasitism observed. | Date parasite emerged. | Days from deposition of eggs to hatching of parasite. |
|---|---|---|---|
| July 24 | Aug. 5 | Aug. 19 | 26 |
| Do | ...do | Aug. 20 | 27 |
| July 27 | Aug. 10 | Aug. 23 | 27 |
| Do | ...do | Aug. 24 | 28 |
| July 28 | Aug. 5 | Aug. 19 | 22 |
| Do | ...do | ...do | 22 |
| Aug. 1 | Aug. 10 | Aug. 22 | 21 |
| Aug. 2 | ...do | ...do | 20 |

The date on which the parasitism was observed can have little to do with the actual date of the parasitization of the egg. As the parasites were very abundant in the vicinity of the eggs it is probable that the latter were stung almost directly after being deposited; consequently the parasites' life cycle would start immediately after the codling-moth eggs had been laid. Figured in this way the life cycle ranges from 20 to 28 days, with an average of 24.16 days. A comparison with the life cycle of the parasite in earlier or first-brood eggs and in eggs of the second brood would be interesting.

In 1909 several parasites were reared from the larvæ of the codling moth by Mr. J. R. Horton, of the Bureau of Entomology. These were all unidentified Hymenoptera. Toward the end of April, 1911, some overwintering full-fed codling moth larvæ were observed by the junior author to have a whitish, distended appearance and upon closer examination proved to have been killed by a hair worm, determined at the instance of Mr. A. L. Quaintance, of the Bureau of Entomology, by Dr. B. H. Ransom, of the Bureau of Animal Industry, as belonging to the family Mermithidæ. These worms, of which there was one in each host, lay coiled up, occupying the entire interior of the larva and exceeding 3 inches in length when uncoiled. None was found in the larvæ of the first or in those of the second broods taken in 1911 from banded trees.

*Predaceous insects.*—In February, 1911, the larvæ, pupæ, and adults of *Melachius auritus* Lec. were found in considerable numbers, apparently preying upon the larvæ of the codling moth. The specimens, on request of Prof. Quaintance, were later determined by Mr. E. A. Schwarz, of the Bureau of Entomology, who said in reference to them: "* * * This and other species of the same genus have repeatedly been reported to the Bureau of Entomology as enemies of the codling moth. The genus (excepting the imported *Malachius æneus* L.) does not occur in the Atlantic slope of North America."

## BAND RECORDS OF 1909.

Through the kindness of Mr. E. Northern, of San Jose, Cal., 20 trees of his orchard were banded to obtain records. The apples are of the Newtown Pippin variety, and the whole orchard, with the exception of the banded trees, is annually treated with several applications of arsenate of lead. The bands were of burlap and were placed at an average of 30 inches from the ground after the loose bark had been scraped off.

A summary of all of the work performed, including the total number of larvæ and pupæ (each collection), the weekly emergence of adults following, and the total number of larvæ which transformed in 1909 and which hibernated until 1911, is shown in Table LII.

TABLE LII.—*Band record for 1909.*

| No. of record. | Date of collecting. | Number of— |  | Total larvæ plus pupæ. | Number of adults emerging from respective collections by— |  |  |  |  |  |  |  |  |  |  |  | Total issued, 1909. | Total issued, 1910. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Larvæ. | Pupæ. |  | July 15. | July 22. | July 29. | Aug. 5. | Aug. 12. | Aug. 19. | Aug. 26. | Sept. 2. | Sept. 9. | Sept. 16. | Sept. 23. | Sept. 30. |  |  |
| 1 | June 21 | 1,602 | 215 | 1,817 | 264 | 378 | 388 | 399 | 402 | 403 | .... | .... | .... | .... | .... | .... | 403 | (1) |
| 2 | June 28 | 2,276 | 79 | 2.355 | 0 | 249 | 607 | 646 | 666 | 677 | 678 | .... | .... | .... | .... | .... | 678 | (1) |
| 3 | July 6 | 946 | 159 | 1,105 | 0 | 0 | 166 | 628 | 690 | 718 | 722 | .... | .... | .... | .... | .... | 722 | (1) |
| 4 | July 9 | 804 | 93 | 897 | 1 | 8 | 27 | 387 | 411 | 422 | 425 | 426 | 426 | 427 | .... | .... | 427 | 122 |
| 5 | July 12 | 761 | 59 | 820 | 0 | 3 | 8 | 159 | 270 | 291 | 294 | 295 | .... | .... | .... | .... | 295 | 121 |
| 6 | July 15 | 885 | 68 | 953 | 0 | 1 | 2 | 9 | 431 | 484 | 492 | 495 | 495 | 496 | .... | .... | 496 | (1) |
| 7 | July 19 | 919 | 48 | 967 | 0 | 1 | 2 | 6 | 84 | 391 | 418 | 429 | 432 | 432 | 433 | .... | 433 | 141 |
| 8 | July 22 | 536 | 37 | 573 | 0 | 0 | 0 | 1 | 3 | 200 | 247 | 258 | 259 | 260 | .... | .... | 260 | 74 |
| 9 | July 26 | 505 | 30 | 535 | 0 | 0 | 0 | 1 | 2 | 37 | 135 | 140 | 146 | 148 | .... | .... | 148 | 143 |
| 10 | July 29 | 350 | 22 | 372 | 0 | 0 | 0 | 0 | 1 | 1 | 66 | 73 | 76 | 78 | 79 | .... | 79 | 133 |
| 11 | Aug. 2 | 297 | 22 | 319 | 0 | 0 | 0 | 0 | 0 | 2 | 12 | 46 | 47 | 48 | .... | .... | 48 | 115 |
| 12 | Aug. 5 | 180 | 16 | 196 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 4 | .... | .... | 4 | 42 |
| 13 | Aug. 9 | 185 | 7 | 192 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 22 | 25 | 26 | .... | 26 | 47 |
| 14 | Aug. 12 | 115 | 10 | 125 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 5 | 8 | 9 | .... | 9 | 82 |
| 15 | Aug. 16 | 112 | 4 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 17 | 18 | 18 | 18 | 55 |
| 16 | Aug. 19 | 262 | 2 | 264 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 103 | 105 | .... | 105 | 129 |
| 17 | Aug. 23 | 383 | 0 | 383 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 18 | .... | 18 | 193 |
| 18 | Aug. 26 | 403 | 3 | 406 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 5 | 5 | 223 |
| 19 | Aug. 31 | 477 | 4 | 481 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 3 | 267 |
| 20 | Sept. 2 | 371 | 4 | 375 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 210 |
| 21 | Sept. 6 | 580 | 0 | 580 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 257 |
| 22 | Sept. 9 | 381 | 0 | 381 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 258 |
| 23 | Sept. 13 | 253 | 0 | 253 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 328 |
| 24 | Sept. 16 | 359 | 1 | 360 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 157 |
| 25 | Sept. 20 | 290 | 0 | 290 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 116 |

[1] Records annulled through larvæ being drowned in winter.

Figure 36 shows graphically the 1909 band record.

## BAND RECORDS OF 1910.

Through the kindness of Mr. W. J. Farrington 12 trees of his orchard at San Jose, Cal., were banded to obtain records of the second-brood larvæ. The apples were of the Skinner Seedling variety; and as this apple ripens early, no records could be taken after August 22, therefore showing practically no second brood of larvæ.

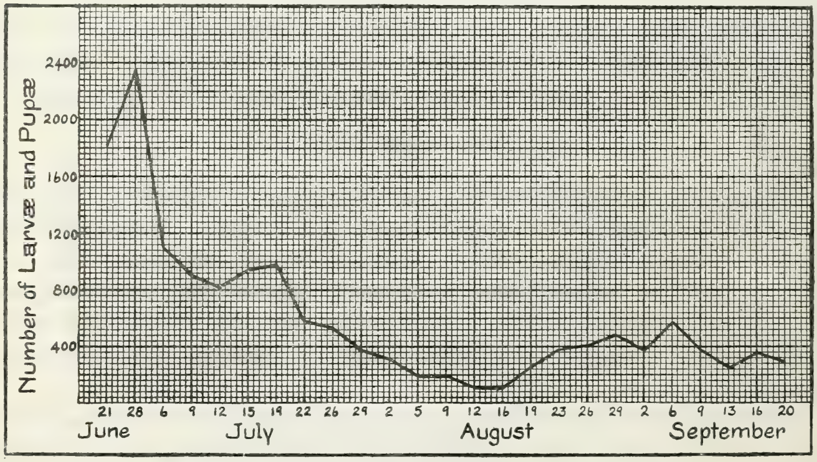

FIG. 36.—Diagram showing band record of 1909. (Original.)

A summary of all the work performed in 1910, including the date of collection, weekly emergence in 1910, and the totals for both 1910 and 1911, is shown in Table LIII.

TABLE LIII.—*Band record for 1910 at San Jose, Cal.*

| No. of record. | Date of collecting. | Number of— |  | Total larvæ plus pupæ. | Number of adults emerging from respective collections by— |  |  |  |  |  |  |  |  |  |  |  | Total issued, 1910. | Total issued, 1911. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Larvæ. | Pupæ. |  | July 14. | July 21. | July 28. | Aug. 4. | Aug. 11. | Aug. 18. | Aug. 25. | Sept. 1. | Sept. 8. | Sept. 15. | Sept. 22. | Sept. 29. |  |  |
| 1...... | June 6 | 22 | 6 | 28 | 8 | 8 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 8 | 0 |
| 2...... | June 13 | 76 | 1 | 77 | 26 | 28 | 29 | 29 | 29 | 29 | 32 | 32 | .... | .... | .... | .... | 32 | 0 |
| 3[1]..... | June 27 | 173 | 0 | 173 | 0 | 50 | 60 | 62 | 62 | 62 | 65 | 66 | 67 | 67 | 68 | 68 | 68 | 33 |
| 4...... | July 4 | 114 | 3 | 117 | 0 | 2 | 27 | 33 | 39 | 42 | 43 | 43 | 44 | 45 | 45 | .... | 45 | 34 |
| 5...... | July 11 | 326 | 28 | 354 | 0 | 1 | 5 | 36 | 95 | 113 | 117 | 121 | 122 | 123 | 123 | .... | 123 | 78 |
| 6...... | July 18 | 203 | 13 | 216 | 0 | 0 | 1 | 1 | 12 | 53 | 70 | 79 | 80 | 80 | 80 | .... | 80 | 32 |
| 7...... | July 25 | 102 | 9 | 111 | 0 | 0 | 0 | 0 | 0 | 2 | 14 | 21 | 22 | 22 | 23 | 23 | 23 | 22 |
| 8...... | Aug. 1 | 41 | 5 | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 9 | 12 | 12 | 12 | .... | 12 | 16 |
| 9...... | Aug. 8 | 18 | 1 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .... | 0 | 7 |
| 10...... | Aug. 15 | 13 | 5 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 7 |
| 11...... | Aug. 22 | 20 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 10 |

[1] The worms collected June 20 were used for individual pupation records and none of this lot was kept for overwintering emergence, so they are excluded from this table.

Figure 37 shows graphically the 1910 band record.

## BAND RECORDS OF 1911.

Ten trees of the Newtown Pippin variety were selected in the orchard of Mr. E. Northern. These trees were banded June 1 with burlap bands of an average width of 8 inches. These trees were left unsprayed while the rest of the orchard was treated with arsenate of lead.

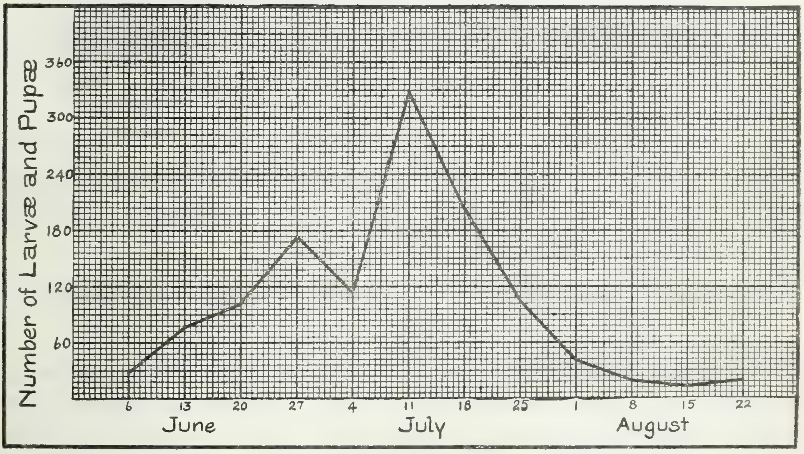

FIG. 37.—Diagram showing band record of 1910. (Original.)

TABLE LIV.—*Band record for 10 apple trees at San Jose, Cal., 1911.*

| Date of collection. | Number of larvæ and pupæ. | Date of collection. | Number of larvæ and pupæ. |
|---|---|---|---|
| July 6.... | 56 | Sept. 7... | 23 |
| July 13... | 91 | Sept. 14.. | 43 |
| July 20... | 84 | Sept. 21.. | 73 |
| July 27... | 52 | Sept. 28.. | 82 |
| Aug. 3... | 40 | Oct. 5.... | 83 |
| Aug. 10.. | 38 | Oct. 12... | 64 |
| Aug. 17.. | 16 | | |
| Aug. 24.. | 15 | | 774 |
| Aug. 31.. | 14 | | |

From this table and the accompanying diagram, figure 38, there can be observed two clearly defined broods, the first of which reached its maximum about July 16 and the second about October 1. After August 10 only two pupæ were collected, so that it can be safely assumed that all the individuals taken after this date belonged to the second or overwintering brood.

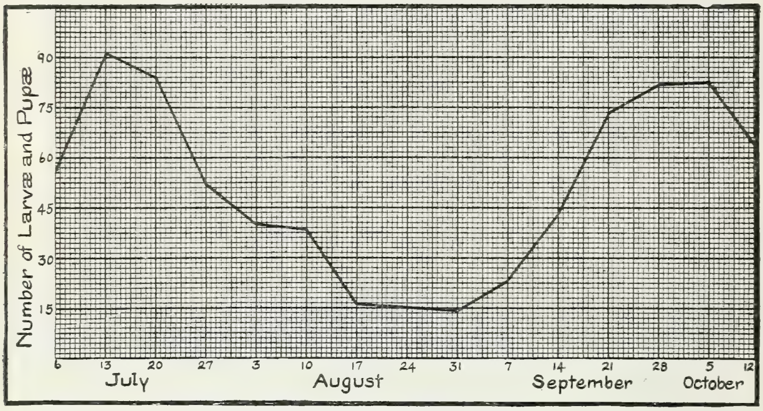

FIG. 38.—Diagram showing band record, Northern orchard, 1911. (Original.)

## FIRST-BROOD EMERGENCE v. OVERWINTERING EMERGENCE, 1911.

From band records collected in 1911 (see Table LIV) 774 larvæ and pupæ were taken. Some of these, from the first collections, were placed in vials for individual pupal records, while the remainder were placed in jars for adult emergence records. Those placed in the vials were all of the first-brood larvæ and only a very small percentage overwintered. The latter collections—both consisting of first-brood and second-brood larvæ—resulted in an emergence of first-brood moths of about 18 per cent. Only 157 moths emerged from these collections, although a considerable number of pupæ died in their vials. Compared with seasons 1909–10 and 1910–11 this was a very small proportion of moths for the first brood as against those hibernating as larvæ, for in both these seasons the advantage lay easily with the first brood. According to these data there appears to be an excellent reason to look for a large overwintering emergence in 1912.

## REVIEW OF LIFE-HISTORY WORK OF 1911.

Similar records on the life history of the codling moth to those kept in 1910 were obtained in 1911. The results of these observations are shown in the diagram, figure 39. Spring pupæ were present about February 20 and continued until June 20, reaching the maximum about April 12. Moths began to emerge about March 24 and continued until June 8, with the maximum emergence occurring about May 8. Eggs of the first brood were deposited from March 24 until July 11, with the maximum deposition taking place about May 12, while the first-brood larvæ hatched from April 23 until July 26, with the maximum hatching period occurring about May 30. First-brood larvæ cocooned from May 25 until August 26, with the maximum cocooning period about June 28. The first-brood pupæ were present from June 30 until September 29, with a maximum period about July 28. First-brood moths began emerging July 17 and continued until September 29, the maximum emergence taking place August 16.

Second-brood eggs were deposited from July 18 until October 4, with the maximum period about August 28, while the larvæ hatched between July 30 and October 18, with a maximum hatching about September 4. The second-brood larvæ began to cocoon August 14 and on throughout the winter, reaching their maximum about September 18. The overwintering part of the first-brood larvæ commenced to cocoon about June 12, but the majority of the overwintering larvæ came from the second brood. The life cycle from the time the spring pupæ appeared until the last first-brood larvæ cocooned occupied a period of six months.

## COMPARISON OF LIFE HISTORY IN 1910 AND 1911.

From a comparison of figures 31 and 39 it is apparent that the main difference exists in the fact that the 1911 season was about two weeks later all through. This is quite to be expected from the colder and later season of 1911. Table LV shows a comparison of the life histories and various stages of the codling moth in 1910 and 1911.

TABLE LV.—*Comparison of life history and stages of the codling moth for 1910 and 1911.*

| Year. | Spring pupæ. | | | First-brood eggs. | | | First-brood larvæ in fruit.[1] | | | First-brood pupæ. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. |
| | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* |
| 1910 | 61 | 29 | 40.7 | 17 | 8 | 12.4 | 103 | 31 | 48.8 | 55 | 11 | 19.04 |
| 1911 | 56 | 30 | 42.4 | 15 | 10 | 12.77 | 42 | 26 | 34.67 | 37 | 18 | 23.12 |

| Year. | Life cycle egg to egg. | | | Second-brood eggs. | | | Second-brood larvæ in fruit. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. |
| | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* |
| 1910 | 101.4 | 58.4 | 78.62 | 17 | 7 | 10.92 | 59 | 30 | 40 |
| 1911 | 77 | 67 | 71.3 | 15 | 11 | 12.5 | 79 | 43 | 58.15 |

[1] This is the sum of the length of life in the fruit and the post-larval stage. Consequently the sum of the two maxima, or 103 days, is theoretical, as the maximum life cycle was only 101.4 days. Similarly the sum of the two minima, or 26 days, is also theoretical.

## WEATHER RECORDS FOR 1909, 1910, AND 1911.

During the three years that the codling moth has been studied at San Jose, Cal., a comparison of the weather conditions influencing the life-history records has been made. These records have been obtained through the United States Weather Bureau Station at San Jose, which is about 3 miles from the laboratory used for studying the codling moth. Table LVI presents the daily mean tempera-

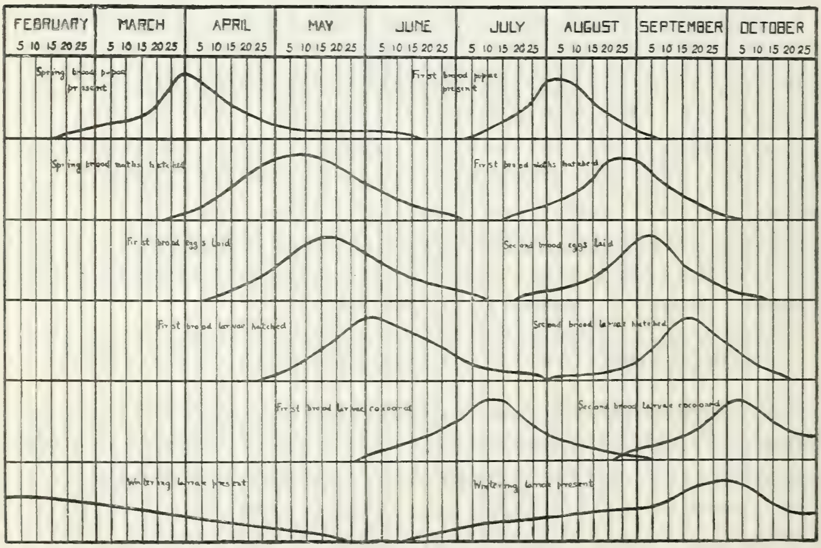

FIG. 39.—Diagram showing seasonal history of the codling moth during the season of 1911. (Original.)

ture for the growing season from February to October, inclusive, for the years 1909, 1910, and 1911; also the mean temperature for the month and the departure from normal.

Table LVII is a summary of Table LVI and shows that in 1909 one month was normal, two were above normal, while the remaining six of the growing season were below normal. The total accumulated mean temperature for the 1909 growing season was 15.9° below the normal, giving an average monthly departure from the normal of −1.76°.

The 1910 season shows four months above the normal and five below, with a total accumulated mean temperature for the growing season of 7.9 below normal, with an average monthly departure from the normal of −0.87°.

The 1911 season shows one month above the normal and the remaining eight below, with a total accumulated mean temperature of 23.7° below normal for the growing season, which gives an average monthly departure from normal of −2.63°.

The 1910 season was much the warmest and 1911 unusually cold—so much so that most stone fruits did not sugar up well. The 1910 season, barring June, which was very cold, was practically a normal growing season.

Looking at the three seasons from a meteorological point of view, one should expect to find the largest percentage of the first-brood larvæ transforming in 1910, with a large second brood indicated by the band record, while 1911 should give the smallest percentage of transforming first-brood larvæ, with a smaller second brood indicated by the band record. The 1909 season should have given a larger percentage of transforming first-brood larvæ than 1911 but less than 1910 and a larger second brood than the 1911 and a smaller one than the 1910 season.

Just what did happen is given under that paragraph comparing the seasonal history of the three years.

TABLE LVI.—*Daily mean temperature for the years 1909, 1910, and 1911 at San Jose, Cal.*

| Date. | 1909 | 1910 | 1911 | Date. | 1909 | 1910 | 1911 |
|---|---|---|---|---|---|---|---|
| | °*F.* | °*F.* | °*F* | | °*F.* | °*F.* | °*F.* |
| Feb. 1..... | 56 | 42 | 54 | Feb. 18..... | 52 | 46 | 54 |
| 2..... | 58 | 43 | 56 | 19..... | 48 | 49 | 48 |
| 3..... | 50 | 41 | 50 | 20..... | 47 | 48 | 46 |
| 4..... | 48 | 43 | 52 | 21..... | 49 | 48 | 48 |
| 5..... | 47 | 44 | 52 | 22..... | 48 | 50 | 48 |
| 6..... | 47 | 44 | 46 | 23..... | 52 | 58 | 48 |
| 7..... | 46 | 50 | 44 | 24..... | 50 | 56 | 50 |
| 8..... | 46 | 48 | 47 | 25..... | 48 | 50 | 44 |
| 9..... | 46 | 52 | 46 | 26..... | 50 | 50 | 43 |
| 10..... | 47 | 50 | 49 | 27..... | 54 | 49 | 40 |
| 11..... | 54 | 49 | 48 | 28..... | 52 | 58 | 42 |
| 12..... | 52 | 51 | 47 | | | | |
| 13..... | 51 | 56 | 44 | Total av. | 50.6 | 48.7 | 46.9 |
| 14..... | 50 | 46 | 40 | Departure from normal for month... | Normal. | −1.9 | −3.7 |
| 15..... | 58 | 46 | 40 | | | | |
| 16..... | 60 | 48 | 41 | | | | |
| 17..... | 54 | 48 | 46 | | | | |

TABLE LVI.—*Daily mean temperature for the years 1909, 1910, and 1911 at San Jose, Cal.*—Continued.

| Date. | 1909 | 1910 | 1911 | Date. | 1909 | 1910 | 1911 |
|---|---|---|---|---|---|---|---|
| | *°F.* | *°F.* | *°F.* | | *°F.* | *°F.* | *°F.* |
| Mar. 1 | 54 | 60 | 44 | May 1 | 67 | 51 | 53 |
| 2 | 54 | 61 | 47 | 2 | 60 | 56 | 59 |
| 3 | 58 | 60 | 53 | 3 | 60 | 52 | 54 |
| 4 | 47 | 54 | 49 | 4 | 59 | 52 | 58 |
| 5 | 47 | 52 | 52 | 5 | 58 | 58 | 54 |
| 6 | 50 | 52 | 51 | 6 | 62 | 59 | 54 |
| 7 | 50 | 54 | 52 | 7 | 60 | 63 | 51 |
| 8 | 50 | 54 | 57 | 8 | 56 | 60 | 54 |
| 9 | 52 | 60 | 50 | 9 | 54 | 65 | 56 |
| 10 | 54 | 58 | 50 | 10 | 53 | 60 | 56 |
| 11 | 53 | 60 | 51 | 11 | 53 | 60 | 57 |
| 12 | 50 | 52 | 54 | 12 | 56 | 60 | 56 |
| 13 | 50 | 55 | 56 | 13 | 58 | 58 | 52 |
| 14 | 52 | 58 | 58 | 14 | 58 | 64 | 56 |
| 15 | 50 | 57 | 58 | 15 | 53 | 70 | 54 |
| 16 | 50 | 62 | 54 | 16 | 52 | 71 | 54 |
| 17 | 50 | 62 | 53 | 17 | 53 | 64 | 56 |
| 18 | 52 | 56 | 57 | 18 | 52 | 62 | 56 |
| 19 | 48 | 54 | 56 | 19 | 56 | 62 | 59 |
| 20 | 46 | 56 | 52 | 20 | 53 | 62 | 67 |
| 21 | 45 | 52 | 53 | 21 | 50 | 58 | 68 |
| 22 | 47 | 54 | 55 | 22 | 52 | 63 | 63 |
| 23 | 50 | 48 | 56 | 23 | 52 | 63 | 56 |
| 24 | 48 | 48 | 58 | 24 | 58 | 62 | 52 |
| 25 | 52 | 52 | 55 | 25 | 60 | 64 | 54 |
| 26 | 50 | 50 | 53 | 26 | 60 | 65 | 53 |
| 27 | 48 | 46 | 58 | 27 | 56 | 62 | 58 |
| 28 | 50 | 52 | 60 | 28 | 55 | 64 | 58 |
| 29 | 48 | 54 | 65 | 29 | 60 | 72 | 56 |
| 30 | 48 | 58 | 66 | 30 | 64 | 78 | 58 |
| 31 | 53 | 60 | 61 | 31 | 70 | 72 | 62 |
| Total av. | 50.5 | 55.3 | 54.6 | Total av. | 57.2 | 62.3 | 56.5 |
| Departure from normal for month | −3.2 | +1.6 | +0.9 | Departure from normal for month | −3.5 | +1.6 | −4.2 |
| Apr. 1 | 56 | 58 | 56 | June 1 | 63 | 65 | 60 |
| 2 | 60 | 53 | 56 | 2 | 63 | 62 | 62 |
| 3 | 55 | 56 | 52 | 3 | 60 | 58 | 62 |
| 4 | 47 | 58 | 56 | 4 | 58 | 58 | 60 |
| 5 | 52 | 56 | 60 | 5 | 56 | 54 | 61 |
| 6 | 54 | 56 | 54 | 6 | 64 | 54 | 60 |
| 7 | 58 | 52 | 51 | 7 | 62 | 57 | 60 |
| 8 | 60 | 56 | 56 | 8 | 58 | 64 | 58 |
| 9 | 64 | 56 | 54 | 9 | 66 | 72 | 62 |
| 10 | 54 | 56 | 50 | 10 | 63 | 62 | 64 |
| 11 | 54 | 52 | 49 | 11 | 60 | 62 | 67 |
| 12 | 58 | 56 | 45 | 12 | 57 | 61 | 60 |
| 13 | 58 | 56 | 48 | 13 | 52 | 54 | 60 |
| 14 | 62 | 58 | 52 | 14 | 56 | 57 | 61 |
| 15 | 64 | 62 | 56 | 15 | 66 | 58 | 64 |
| 16 | 62 | 62 | 56 | 16 | 60 | 58 | 64 |
| 17 | 62 | 66 | 60 | 17 | 56 | 56 | 65 |
| 18 | 51 | 59 | 53 | 18 | 57 | 55 | 68 |
| 19 | 50 | 60 | 56 | 19 | 60 | 58 | 64 |
| 20 | 52 | 58 | 56 | 20 | 62 | 56 | 62 |
| 21 | 54 | 61 | 56 | 21 | 63 | 56 | 55 |
| 22 | 56 | 66 | 57 | 22 | 70 | 56 | 54 |
| 23 | 57 | 72 | 57 | 23 | 78 | 62 | 58 |
| 24 | 59 | 68 | 57 | 24 | 68 | 65 | 58 |
| 25 | 58 | 58 | 58 | 25 | 65 | 70 | 61 |
| 26 | 62 | 57 | 50 | 26 | 64 | 64 | 70 |
| 27 | 56 | 54 | 50 | 27 | 59 | 60 | 62 |
| 28 | 56 | 53 | 53 | 28 | 58 | 58 | 60 |
| 29 | 59 | 53 | 50 | 29 | 56 | 59 | 58 |
| 30 | 64 | 54 | 50 | 30 | 62 | 62 | 64 |
| Total av. | 57.1 | 58.1 | 53.8 | Total av. | 61.4 | 59.8 | 61.5 |
| Departure from normal for month | +0.5 | +1.5 | −2.8 | Departure from normal for month | −3.6 | −5.2 | −3.5 |

TABLE LVI.—*Daily mean temperature for the years 1909, 1910, and 1911 at San Jose, Cal.*—Continued.

| Date. | 1909 | 1910 | 1911 |
|---|---|---|---|
|  | °*F.* | °*F.* | °*F.* |
| July 1 | 66 | 56 | 70 |
| 2 | 61 | 57 | 67 |
| 3 | 60 | 56 | 65 |
| 4 | 56 | 64 | 64 |
| 5 | 60 | 66 | 68 |
| 6 | 61 | 70 | 66 |
| 7 | 66 | 71 | 66 |
| 8 | 62 | 70 | 70 |
| 9 | 64 | 68 | 68 |
| 10 | 64 | 67 | 66 |
| 11 | 68 | 65 | 68 |
| 12 | 73 | 67 | 66 |
| 13 | 68 | 66 | 64 |
| 14 | 68 | 66 | 66 |
| 15 | 68 | 63 | 68 |
| 16 | 62 | 66 | 68 |
| 17 | 60 | 70 | 64 |
| 18 | 62 | 72 | 62 |
| 19 | 56 | 74 | 62 |
| 20 | 66 | 71 | 61 |
| 21 | 63 | 65 | 60 |
| 22 | 68 | 66 | 62 |
| 23 | 64 | 66 | 64 |
| 24 | 65 | 62 | 65 |
| 25 | 63 | 66 | 71 |
| 26 | 61 | 64 | 68 |
| 27 | 66 | 64 | 65 |
| 28 | 66 | 65 | 66 |
| 29 | 65 | 64 | 66 |
| 30 | 64 | 62 | 70 |
| 31 | 65 | 60 | 67 |
| Total av | 63.8 | 65.5 | 65.8 |
| Departure from normal for month | −3.1 | −1.4 | −1.1 |
| Aug. 1 | 67 | 62 | 62 |
| 2 | 66 | 65 | 64 |
| 3 | 68 | 62 | 66 |
| 4 | 68 | 64 | 62 |
| 5 | 62 | 66 | 62 |
| 6 | 67 | 65 | 63 |
| 7 | 62 | 62 | 62 |
| 8 | 64 | 64 | 60 |
| 9 | 64 | 62 | 60 |
| 10 | 61 | 63 | 61 |
| 11 | 60 | 60 | 61 |
| 12 | 58 | 62 | 58 |
| 13 | 61 | 66 | 58 |
| 14 | 63 | 65 | 59 |
| 15 | 63 | 66 | 59 |
| 16 | 68 | 68 | 60 |
| 17 | 73 | 62 | 60 |
| 18 | 70 | 62 | 62 |
| 19 | 68 | 63 | 62 |
| 20 | 66 | 60 | 66 |
| 21 | 63 | 64 | 61 |
| 22 | 60 | 69 | 66 |
| 23 | 62 | 72 | 63 |
| 24 | 66 | 70 | 66 |
| 25 | 70 | 66 | 63 |
| 26 | 68 | 65 | 62 |
| 27 | 68 | 60 | 63 |
| 28 | 62 | 61 | 62 |
| 29 | 62 | 68 | 68 |
| 30 | 59 | 67 | 69 |
| 31 | 63 | 64 | 64 |
| Total av | 64.6 | 64.4 | 62.4 |
| Departure from normal for month | −2.1 | −2.3 | −4.3 |
| Sept. 1 | 64 | 64 | 62 |
| 2 | 62 | 63 | 62 |
| 3 | 64 | 60 | 62 |
| 4 | 64 | 64 | 62 |
| 5 | 62 | 62 | 61 |
| 6 | 64 | 61 | 62 |
| 7 | 63 | 60 | 65 |
| 8 | 68 | 61 | 60 |
| 9 | 69 | 66 | 60 |
| 10 | 63 | 67 | 58 |
| 11 | 67 | 59 | 60 |
| 12 | 70 | 56 | 60 |
| 13 | 70 | 58 | 62 |
| 14 | 72 | 60 | 66 |
| 15 | 74 | 62 | 63 |
| 16 | 73 | 60 | 62 |
| 17 | 65 | 62 | 64 |
| 18 | 64 | 58 | 64 |
| 19 | 62 | 62 | 62 |
| 20 | 62 | 62 | 63 |
| 21 | 66 | 64 | 58 |
| 22 | 68 | 65 | 63 |
| 23 | 62 | 64 | 64 |
| 24 | 64 | 63 | 57 |
| 25 | 59 | 62 | 58 |
| 26 | 64 | 62 | 58 |
| 27 | 63 | 59 | 56 |
| 28 | 62 | 60 | 59 |
| 29 | 60 | 66 | 63 |
| 30 | 56 | 68 | 58 |
| Total av | 64.8 | 62.0 | 61.0 |
| Departure from normal for month | +0.1 | −2.7 | −3.7 |
| Oct. 1 | 54 | 60 | 56 |
| 2 | 60 | 59 | 56 |
| 3 | 56 | 58 | 56 |
| 4 | 60 | 62 | 55 |
| 5 | 62 | 64 | 56 |
| 6 | 60 | 70 | 60 |
| 7 | 60 | 72 | 67 |
| 8 | 64 | 70 | 60 |
| 9 | 68 | 56 | 55 |
| 10 | 70 | 55 | 55 |
| 11 | 66 | 54 | 59 |
| 12 | 62 | 56 | 60 |
| 13 | 60 | 61 | 58 |
| 14 | 61 | 58 | 62 |
| 15 | 54 | 58 | 66 |
| 16 | 56 | 62 | 68 |
| 17 | 58 | 69 | 68 |
| 18 | 56 | 66 | 67 |
| 19 | 61 | 66 | 64 |
| 20 | 64 | 64 | 58 |
| 21 | 60 | 60 | 56 |
| 22 | 59 | 56 | 55 |
| 23 | 62 | 60 | 56 |
| 24 | 64 | 61 | 62 |
| 25 | 62 | 63 | 64 |
| 26 | 56 | 62 | 52 |
| 27 | 54 | 62 | 56 |
| 28 | 54 | 60 | 55 |
| 29 | 51 | 59 | 56 |
| 30 | 50 | 57 | 57 |
| 31 | 52 | 58 | 56 |
| Total av | 59.3 | 61.2 | 59.0 |
| Departure from normal for month | −1.0 | +0.9 | −1.3 |

TABLE LVII.—*A summary of Table LVI, showing the departures from normal of the average mean temperature for the growing season 1909, 1910, 1911, at San Jose, Cal.*

| Month. | Departure from normal in— | | |
|---|---|---|---|
| | 1909 | 1910 | 1911 |
| | °*F.* | °*F.* | °*F.* |
| February | Normal. | −1.9 | − 3.7 |
| March | − 3.2 | +1.6 | + .9 |
| April | + .5 | +1.5 | − 2.8 |
| May | − 3.5 | +1.6 | − 4.2 |
| June | − 3.6 | −5.2 | − 3.5 |
| July | − 3.1 | −1.4 | − 1.1 |
| August | − 2.1 | −2.3 | − 4.3 |
| September | + .1 | −2.7 | − 3.7 |
| October | − 1.0 | + .9 | − 1.3 |
| Total | −15.9 | −7.9 | −23.7 |
| Average monthly departure from normal | − 1.76 | − .87 | − 2.63 |

## COMPARATIVE LIFE-HISTORY STUDIES FOR THE SEASON OF 1909, 1910, AND 1911.

The temperature conditions (see Table LVI) indicated that 1910 was a very warm season favorable for the development of the codling moth, while the 1911 season was very cold and unfavorable to this insect, with 1909 an intermediate season. The 1910 season, while apparently very warm, was a more normal season than the other two.

On account of many lacking life-history records in 1909 but with a good band record, and a poor band record in 1910 but with complete life-history records, it is impossible to make perfect comparisons of the three seasons. An examination of both band records and rearing experiments shows the following data, however. (See Table LVIII.)

TABLE LVIII.—*Summary of the band records for 1909, 1910, and 1911 along with rearing results, showing the comparative size of the broods and relative number of transforming and wintering larvæ.*

| Larval collections. | Percentages for— | | |
|---|---|---|---|
| | 1909 | 1910 | 1911 |
| Transforming larvæ—total band collection | 27.6 | (1) | 18.0 |
| Wintering larvæ—total band collection | 72.4 | (1) | 82.0 |
| Relative proportion of first-brood larvæ | 95.0 | [2] +50.0 | 50.0 |
| Relative proportion of second-brood larvæ | 5.0 | [2] +50.0 | 50.0 |
| Transforming larvæ of first brood | 33.5 | 33.4 | 40.0 |
| Wintering larvæ of first brood | 66.5 | 66.6 | 60.0 |

[1] Band record from summer apples.

[2] Approximately (from rearing records).

The results as indicated by Table LVIII are not entirely in conformity with expectations.

The relative proportions for the broods for 1909 and 1910 appear correct in comparison with the weather conditions, but the relative proportions for 1911 seem incorrect after examining the weather conditions for that year. Theoretically, on account of the very cold season there should have been a large first brood and a small second brood, which is further borne out by the small percentage of transforming larvæ of the total band collection. One fact is evident, however, there were more codling-moth larvæ present in the field in 1909 and 1910, which gave a larger series in the band records for these years in comparison with 1911.

The 1911 season was apparently so cold early that moths did not oviposit properly and the temperature conditions probably exerted such an influence that the infestation was light, therefore cutting down both broods and making them nearly equal.

## CONTROL OF THE CODLING MOTH ON PEARS AND APPLES IN THE SANTA CLARA VALLEY.

While prunes, apricots, and cherries are the chief fruits raised in this valley, there are about 500 acres set to apples and 1,400 acres to pears. These orchards on the whole have probably paid better financially the past five years than many orchards of the first three varieties of fruits. Situated as they are, on the lower and wet but rich soils near Alviso, they have escaped the attacks of the chief insect pest to deciduous fruits in central California, the pear thrips (*Euthrips pyri* Daniel). The codling moth, aside from several species of plant-lice, has been practically the only insect worthy of the attention of apple and pear growers in the Santa Clara Valley.

It is needless to say that spraying, both good and bad, has been practiced for the codling moth, but the majority of the fruit growers have either sprayed at the wrong time or in an indifferent manner or have used ineffective poisons.

The writers have seen apple orchards that had been sprayed three times during the season and these had from 75 to 80 per cent wormy fruit. Until the past two or three years there was a tendency to do slipshod work at low pressure, and even now many growers try to use too many leads of hose and to cover more trees with too little material. The practice of using four lines of hose on one spray outfit should be discouraged since it is difficult to maintain a sufficiently high pressure and the nozzle men frequently interfere with one another. It would be much better business to use more spray outfits, and even to spray from a tower.

Data are presented here from one apple orchard and one pear orchard where the spraying was done after the directions of this bureau. On both orchards the work was in the nature of a commercial demonstration and it is in a way unfortunate that no checks could be obtained on the pear orchard, which was sprayed two successive years, although the early history of the place is known.

## THE O'TOOLE PEAR ORCHARD AT ALVISO, CAL.

This orchard lies on a road intersecting the Alviso and Milpitas Roads about 6 miles north of San Jose and is, strictly speaking, in the Alviso section of the Santa Clara Valley. The soil is entirely "made soil," the orchard itself being surrounded by a high levee. The type of soil is a very rich sandy loam styled "Fresno sandy loam" on the map by the United States Geological Survey. This orchard, 30 acres in extent, is composed of six varieties of pears and the trees are some of the finest in the State of California, many of them reaching a diameter of 8 to 10 inches at the base.

During the years 1910 and 1911 the writers have, through the courtesy of Mr. George Reed, manager of this orchard for the Anderson Fruit Co., been able to obtain figures on the wormy and nonwormy fruit. Mr. Reed, in talking with the authors, stated that the orchard usually contained from 15 to 60 per cent wormy fruit before it was placed in his hands, even when sprayed for the codling moth. The early Bartlett pears were seldom extremely wormy, but late varieties, such as the Winter Nelis and Easter Beurré, frequently had more wormy pears than clean ones.

One peculiar fact relating to this orchard should be mentioned here. The west and north sides are closed in by a levee of the Coyote Creek, which is about 10 feet high. This has caused the orchard to blossom and mature its fruit about 10 days earlier than other orchards in the vicinity and has therefore made earlier spraying necessary also.

*Spraying operations.*—A power outfit was used both years at a high pressure and arsenate of lead as a poison at the rate of 2 pounds to 50 gallons of water. An old spraying outfit was used in 1910 and a new one in 1911; consequently much better work was done in the latter year.

In all of the spraying large-chamber nozzles were used, one to each spray rod. All of the work was done from the ground, the men using 12-foot rods and 50-foot lengths of hose.

Since no check on the spraying was left, no figures are presented here on the cost of spraying and the benefit derived, but a summary is given of the wormy and sound fruit of the trees examined under each variety.

*Season of 1910.*—The fallen fruit was collected under five trees weekly throughout the season and examined for the entrance place of the worms on each of the six varieties. (See Table LIX.)

Table LIX.—*Results of spraying for codling moth on pears, Alviso, Cal., 1910.*

DATES OF SPRAYING: APR. 5, MAY 4, AND MAY 23.

| Variety of pear and number of trees. | Fruit on ground. | | | | | | Fruit on tree. | | | | | | Total not wormy. | Total wormy. | Total fruit. | Per-centage wormy on ground. | Per-centage wormy on tree. | Total per-centage wormy. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Not wormy. | Wormy. | Where worms entered. | | | Total. | Not wormy. | Wormy. | Where worms entered. | | | Total. | | | | | | |
| | | | Calyx. | Side. | Stem. | | | | Calyx. | Side. | Stem. | | | | | | | |
| Vicars: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 162 | 12 | 3 | 9 | 0 | 174 | 620 | 3 | 0 | 3 | 0 | 623 | 782 | 15 | 797 | 6.97 | 0.48 | 1.79 |
| Tree 2 | 91 | 39 | 12 | 26 | 1 | 130 | 1,411 | 25 | 16 | 9 | 0 | 1,436 | 1,502 | 64 | 1,566 | 30.00 | 1.74 | 4.09 |
| Tree 3 | 324 | 28 | 8 | 20 | 0 | 352 | 1,148 | 11 | 8 | 2 | 1 | 1,159 | 1,472 | 39 | 1,511 | 7.96 | .95 | 2.58 |
| Tree 4 | 16 | 17 | 0 | 17 | 0 | 33 | 823 | 14 | 3 | 11 | 0 | 837 | 839 | 31 | 870 | 51.52 | 1.67 | 3.56 |
| Tree 5 | 185 | 20 | 1 | 19 | 0 | 205 | 1,145 | 13 | 3 | 10 | 0 | 1,158 | 1,330 | 33 | 1,363 | 9.76 | 1.12 | 2.42 |
| Trees 1-5 combined | 778 | 116 | 24 | 91 | 1 | 894 | 5,147 | 66 | 30 | 35 | 1 | 5,213 | 5,925 | 182 | 6,107 | 12.97 | 1.26 | 2.98 |
| Comice: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 315 | 8 | 2 | 6 | 0 | 323 | 775 | 8 | 4 | 3 | 1 | 783 | 1,090 | 16 | 1,106 | 2.47 | 1.02 | 1.44 |
| Tree 2 | 265 | 2 | 1 | 1 | 0 | 267 | 282 | 2 | 2 | 0 | 0 | 284 | 547 | 4 | 551 | .75 | .70 | .73 |
| Tree 3 | 198 | 2 | 1 | 1 | 0 | 200 | 330 | 16 | 11 | 4 | 1 | 346 | 528 | 18 | 546 | 1.00 | 4.62 | 3.29 |
| Tree 4 | 322 | 14 | 4 | 9 | 1 | 346 | 581 | 14 | 13 | 1 | 0 | 595 | 913 | 28 | 941 | 4.05 | 2.19 | 2.98 |
| Tree 5 | 360 | 9 | 2 | 7 | 0 | 369 | 693 | 20 | 17 | 3 | 0 | 713 | 1,053 | 29 | 1,082 | 2.44 | 2.80 | 2.68 |
| Trees 1-5 combined | 1,470 | 35 | 10 | 24 | 1 | 1,505 | 2,661 | 60 | 47 | 11 | 2 | 2,721 | 4,131 | 95 | 4,226 | 2.33 | 2.21 | 2.24 |
| Bartlett: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 81 | 14 | 8 | 6 | 0 | 95 | 1,330 | 22 | 7 | 14 | 1 | 1,352 | 1,411 | 36 | 1,447 | 14.73 | 1.63 | 2.48 |
| Tree 2 | 94 | 9 | 4 | 4 | 1 | 103 | 1,594 | 22 | 10 | 10 | 2 | 1,616 | 1,688 | 31 | 1,719 | 8.73 | 1.39 | 1.80 |
| Tree 3 | 36 | 10 | 6 | 4 | 0 | 46 | 900 | 15 | 10 | 3 | 2 | 915 | 936 | 25 | 961 | 21.74 | 1.64 | 2.60 |
| Tree 4 | 88 | 36 | 21 | 13 | 2 | 124 | 1,082 | 26 | 14 | 12 | 0 | 1,108 | 1,170 | 62 | 1,232 | 29.03 | 2.34 | 5.03 |
| Tree 5 | 76 | 11 | 4 | 7 | 0 | 87 | 964 | 3 | 0 | 3 | 0 | 967 | 1,040 | 14 | 1,054 | 12.64 | .31 | 1.33 |
| Trees 1-5 combined | 375 | 80 | 43 | 34 | 3 | 455 | 5,870 | 88 | 41 | 42 | 5 | 5,958 | 6,245 | 168 | 6,413 | 17.58 | 1.47 | 2.62 |
| Clargeau: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 68 | 28 | 9 | 17 | 2 | 96 | 449 | 7 | 2 | 5 | 0 | 456 | 517 | 35 | 552 | 29.17 | 1.53 | 6.34 |
| Tree 2 | 101 | 19 | 4 | 15 | 0 | 120 | 232 | 4 | 0 | 4 | 0 | 236 | 333 | 23 | 356 | 15.83 | 1.69 | 6.46 |
| Tree 3 | 77 | 23 | 13 | 10 | 0 | 100 | 904 | 3 | 3 | 0 | 0 | 907 | 981 | 26 | 1,007 | 23.00 | .33 | 2.58 |
| Trees 1-3 combined | 246 | 70 | 26 | 42 | 2 | 316 | 1,585 | 14 | 5 | 9 | 0 | 1,599 | 1,831 | 84 | 1,915 | 22.15 | .87 | 4.38 |

TABLE LIX.—*Results of spraying for codling moth on pears, Alviso, Cal., 1910*—Continued.

DATES OF SPRAYING: APRIL 5, MAY 4, AND MAY 23—Continued.

| Variety of pear and number of trees. | Fruit on ground. | | | | | | Fruit on tree. | | | | | | Total. not wormy. | Total wormy. | Total fruit. | Per-centage wormy on ground. | Per-centage wormy on tree. | Total per-centage wormy. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Not wormy. | Wormy. | Where worms entered. | | | Total. | Not wormy. | Wormy. | Where worms entered. | | | Total. | | | | | | |
| | | | Calyx. | Side. | Stem. | | | | Calyx. | Side. | Stem. | | | | | | | |
| Winter Nelis: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 53 | 14 | 4 | 8 | 2 | 67 | 713 | 12 | 8 | 3 | 1 | 725 | 766 | 26 | 792 | 20.89 | 1.65 | 3.28 |
| Tree 2 | 39 | 30 | 9 | 18 | 3 | 69 | 564 | 16 | 8 | 6 | 2 | 580 | 603 | 46 | 649 | 43.48 | 2.76 | 7.09 |
| Tree 3 | 21 | 14 | 1 | 11 | 2 | 35 | 393 | 15 | 7 | 4 | 4 | 408 | 414 | 29 | 443 | 40.00 | 3.65 | 6.54 |
| Tree 4 | 4 | 9 | 3 | 6 | 0 | 13 | 663 | 11 | 4 | 7 | 0 | 674 | 667 | 20 | 687 | 69.23 | 1.63 | 2.91 |
| Trees 1-4 combined | 117 | 67 | 17 | 43 | 7 | 184 | 2,333 | 54 | 27 | 20 | 7 | 2,387 | 2,450 | 121 | 2,571 | 36.41 | 2.26 | 4.70 |
| Easter Beurré: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 216 | 33 | 5 | 26 | 2 | 249 | 1,357 | 25 | 5 | 16 | 4 | 1,382 | 1,573 | 58 | 1,631 | 13.25 | 1.80 | 3.55 |
| Tree 2 | 138 | 27 | 8 | 17 | 2 | 165 | 670 | 32 | 11 | 18 | 3 | 702 | 808 | 59 | 867 | 16.36 | 4.56 | 6.80 |
| Tree 3 | 206 | 29 | 4 | 20 | 5 | 235 | 1,139 | 61 | 17 | 35 | 9 | 1,200 | 1,345 | 90 | 1,435 | 12.34 | 5.08 | 6.27 |
| Tree 4 | 287 | 35 | 3 | 28 | 4 | 322 | 1,222 | 20 | 5 | 13 | 2 | 1,242 | 1,509 | 55 | 1,564 | 10.87 | 1.61 | 3.61 |
| Tree 5 | 265 | 21 | 3 | 17 | 1 | 286 | 725 | 8 | 1 | 2 | 5 | 733 | 990 | 29 | 1,019 | 7.34 | 1.09 | 2.84 |
| Trees 1-5 combined | 1,112 | 145 | 23 | 108 | 14 | 1,257 | 5,113 | 146 | 39 | 84 | 23 | 5,259 | 6,225 | 291 | 6,516 | 11.53 | 2.77 | 4.46 |

Table LIX shows the detailed summaries of this work and that the five trees of Vicar pears averaged 2.98 per cent wormy fruit, including windfalls. The Doyenne du Comice averaged 2.24 per cent wormy, the Bartlett 2.62 per cent, the Buerré Clargeau 4.38 per cent, the Winter Nelis 4.70 per cent, and the Easter Buerré 4.46 per cent. It should be noted that the last three varieties show nearly twice the wormy fruit that the other varieties do. This can be explained by the fact that they are later in maturing and hence give the second brood of the codling moth a much better chance to work. The senior author has frequently observed that Bartlett pears in the Santa Clara Valley usually escape nearly all of the second brood of codling moth by being picked so early. A comparison of the dates of spraying with the life-history records will show that most of the spraying was timed a little early, even allowing 10 days because it is an extremely early orchard.

*Season of 1911.*—This year the spraying was accomplished in a more through manner and at a more opportune time, the first application from April 12 to 15, or just as most varieties were shedding the petals; the second application from June 1 to 4; and the third from July 5 to 9. Only two trees were examined in each variety and the work was done weekly as in 1910. All the fruit at picking time on the indicated trees was examined.

Table LX gives a summary of the work performed.

TABLE LX.—*Results of spraying for codling moth on pears, Alviso, Cal., 1911.*

DATES OF SPRAYING: APRIL 12-15, JUNE 1-4, AND JULY 5-9

| Variety of pear and No. of tree. | Fruit on ground. | | | | | | Fruit on tree. | | | | | | Total not wormy. | Total wormy. | Total fruit. | Percentage wormy on ground. | Percentage wormy on tree. | Total percentage wormy. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Not wormy. | Wormy. | Where worms entered. | | | Total. | Not wormy. | Wormy. | Where worms entered. | | | Total. | | | | | | |
| | | | Calyx. | Side. | Stem. | | | | Calyx. | Side. | Stem. | | | | | | | |
| Vicars: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 41 | 10 | 3 | 6 | 1 | 51 | 1,084 | 16 | 6 | 9 | 1 | 1,100 | 1,125 | 26 | 1,151 | 19.0 | 1.45 | 2.16 |
| Tree 2 | 4 | 0 | 0 | 0 | 0 | 4 | 312 | 3 | 2 | 1 | 0 | 315 | 316 | 3 | 319 | .0 | .95 | .94 |
| Trees 1-2 combined | 45 | 10 | 3 | 6 | 1 | 55 | 1,396 | 19 | 8 | 10 | 1 | 1,415 | 1,441 | 29 | 1,470 | 18.18 | 1.34 | 1.97 |
| Comice: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 6 | 1 | 1 | 0 | 0 | 7 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 14.28 | ...... | ...... |
| Tree 2 | 35 | 3 | 1 | 2 | 0 | 38 | 289 | 5 | 1 | 3 | 1 | 294 | 324 | 8 | 332 | 7.89 | 1.70 | 2.40 |
| Trees 1-2 combined | 41 | 4 | 2 | 2 | 0 | 45 | 289 | 5 | 1 | 3 | 1 | 294 | 330 | 9 | 339 | 8.89 | 1.70 | 2.65 |
| Bartlett: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 19 | 2 | 1 | 1 | 0 | 21 | 1,114 | 9 | 4 | 5 | 0 | 1,123 | 1,133 | 11 | 1,144 | 9.52 | .80 | .96 |
| Tree 2 | 100 | 0 | 0 | 0 | 0 | 100 | 1,010 | 5 | 5 | 0 | 0 | 1,015 | 1,110 | 5 | 1,115 | .0 | .49 | .45 |
| Trees 1-2 combined | 119 | 2 | 1 | 1 | 0 | 121 | 2,124 | 14 | 9 | 5 | 0 | 2,138 | 2,243 | 16 | 2,259 | 1.65 | .65 | .70 |
| Clargeau: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 29 | 1 | 1 | 0 | 0 | 30 | 813 | 7 | 5 | 2 | 0 | 820 | 842 | 8 | 850 | 3.33 | .85 | .94 |
| Tree 2 | 2 | 0 | 0 | 0 | 0 | 2 | 197 | 0 | 0 | 0 | 0 | 197 | 199 | 0 | 199 | .0 | .0 | .0 |
| Trees 1-2 combined | 31 | 1 | 1 | 0 | 0 | 32 | 1,010 | 7 | 5 | 2 | 0 | 1,017 | 1,041 | 8 | 1,049 | 3.12 | .69 | .76 |
| Winter Nelis: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 12 | 1 | 0 | 1 | 0 | 13 | 997 | 3 | 3 | 0 | 0 | 1,000 | 1,009 | 4 | 1,013 | 7.7 | .30 | .39 |
| Tree 2 | 20 | 1 | 0 | 1 | 0 | 21 | 1,837 | 2 | 1 | 1 | 0 | 1,839 | 1,857 | 3 | 1,860 | 4.76 | .11 | .16 |
| Trees 1-2 combined | 32 | 2 | 0 | 2 | 0 | 34 | 2,834 | 5 | 4 | 1 | 0 | 2,839 | 2,866 | 7 | 2,873 | 5.88 | .17 | .24 |
| Easter Buerré: | | | | | | | | | | | | | | | | | | |
| Tree 1 | 131 | 1 | 0 | 1 | 0 | 132 | 1,115 | 2 | 0 | 2 | 0 | 1,117 | 1,246 | 3 | 1,249 | .75 | .18 | .24 |
| Tree 2 | 44 | 0 | 0 | 0 | 0 | 44 | 809 | 2 | 0 | 2 | 0 | 811 | 853 | 2 | 855 | .0 | .246 | .245 |
| Trees 1-2 combined | 175 | 1 | 0 | 1 | 0 | 176 | 1,924 | 4 | 0 | 4 | 0 | 1,928 | 2,099 | 5 | 2,104 | .56 | .21 | .237 |

This year, 1911, all of the varieties yielded a larger percentage of clean fruit, the Vicars averaging 1.97 per cent wormy, the Doyenne du Comice 2.65 per cent, the Bartletts 0.70 per cent, the Buerré Clargeau 0.76 per cent, the Winter Nelis 0.24 per cent, and the Easter Buerré 0.237 per cent.

Probably one of the reasons the later varieties were as free from worms in 1911 as the early varieties was that the third application for second-brood larvæ was better timed and was more thorough.

### THE NORTHERN APPLE ORCHARD.

*Season of 1911.*—Through the courtesy of Mr. E. Northern the writers were able to examine weekly 5 sprayed and 5 unsprayed apple trees of the Newtown Pippin variety for wormy fruit. All of Mr. Northern's orchard of 11 acres was sprayed by him with a hand outfit at fair pressure except 5 trees unsprayed left for a check. While it is hardly fair to compare the work of a hand outfit with that of a power outfit, Mr. Northern obtained excellent results, although with a much higher percentage of wormy fruit than Mr. Reed obtained on his pear orchard.

The spraying was done on May 9, June 9, and July 26. The whole orchard was in full bloom by April 18, and by May 1 nearly all the trees had dropped their petals. In all the spraying 2 pounds of arsenate of lead were used to 50 gallons of water and with no fungicide.

Table LXI shows the details of the results obtained on the "Northern orchard."

TABLE LXI.—*Results of spraying for codling moth on apples, Mr. E. Northern's orchard, season of 1911. Variety, Newtown Pippin.*

SPRAYED MAY 9, JUNE 9, AND JULY 25

| No. of tree. | Windfalls. | | | | | | Fruit on tree. | | | | | | Total not wormy. | Total wormy. | Total fruit. | Percentage wormy on ground. | Percentage wormy on tree. | Total percentage wormy. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Not wormy. | Wormy. | Where worms entered. | | | Total. | Not wormy. | Wormy. | Where worms entered. | | | Total. | | | | | | |
| | | | Calyx. | Side. | Stem. | | | | Calyx. | Side. | Stem. | | | | | | | |
| Tree 1 | 335 | 37 | 15 | 18 | 4 | 372 | 385 | 13 | 5 | 7 | 1 | 398 | 720 | 50 | 770 | 9.94 | 3.26 | 6.49 |
| Tree 2 | 454 | 41 | 6 | 26 | 9 | 495 | 635 | 69 | 21 | 42 | 6 | 704 | 1,089 | 110 | 1,199 | 8.28 | 9.8 | 9.17 |
| Tree 3 | 275 | 31 | 9 | 17 | 5 | 306 | 243 | 22 | 6 | 9 | 7 | 265 | 518 | 53 | 571 | 10.03 | 8.3 | 9.28 |
| Tree 4 | 592 | 99 | 25 | 66 | 8 | 691 | 417 | 69 | 26 | 39 | 4 | 486 | 1,009 | 168 | 1,177 | 14.32 | 14.19 | 14.27 |
| Tree 5 | 769 | 80 | 39 | 33 | 8 | 849 | 806 | 83 | 28 | 44 | 11 | 889 | 1,575 | 163 | 1,738 | 9.42 | 9.33 | 9.37 |
| Trees 1–5 combined | 2,425 | 288 | 94 | 160 | 34 | 2,713 | 2,486 | 256 | 86 | 141 | 29 | 2,742 | 4,911 | 544 | 5,455 | 10.61 | 9.33 | 9.97 |
| UNSPRAYED. | | | | | | | | | | | | | | | | | | |
| Tree 1a | 74 | 374 | 182 | 161 | 31 | 448 | 125 | 112 | 49 | 54 | 9 | 237 | 199 | 486 | 685 | 83.48 | 47.26 | 70.94 |
| Tree 2a | 111 | 426 | 212 | 177 | 37 | 537 | 163 | 108 | 46 | 52 | 10 | 271 | 274 | 534 | 808 | 79.33 | 39.86 | 66.09 |
| Tree 3a | 46 | 55 | 24 | 26 | 5 | 101 | 41 | 17 | 6 | 9 | 2 | 58 | 87 | 72 | 159 | 54.45 | 29.31 | 45.28 |
| Tree 4a | 205 | 971 | 460 | 435 | 76 | 1,176 | 268 | 457 | 214 | 208 | 35 | 725 | 473 | 1,428 | 1,901 | 82.57 | 63.03 | 75.11 |
| Tree 5a | 150 | 982 | 539 | 358 | 85 | 1,132 | 140 | 354 | 178 | 148 | 28 | 494 | 270 | 1,336 | 1,626 | 86.75 | 71.83 | 82.16 |
| Trees 1a–5a combined | 586 | 2,808 | 1,417 | 1,157 | 234 | 3,394 | 737 | 1,048 | 493 | 471 | 84 | 1,785 | 1,323 | 3,856 | 5,179 | 82.73 | 58.71 | 74.45 |

The five sprayed trees under observation show a range in wormy fruit from 6.49 to 14.27 per cent, with an average of 9.97 per cent, while the five unsprayed trees ranged from 45.28 to 82.16 per cent wormy fruit.

The five sprayed trees averaged 90.03 per cent sound fruit, while the checks averaged only 25.45 per cent sound fruit, the spraying thus giving a benefit of 64.58 per cent sound fruit on the sprayed trees.

It is evident that the second brood of larvæ caused a large percentage of wormy fruit both on the sprayed and unsprayed trees. The wormy fruit on the five sprayed trees at picking time ranged from 14.19 per cent, and since most of the apples affected by the first brood had fallen off before this nearly all of the injury can be charged to the second-brood larvæ.

## CONCLUSIONS FROM EXPERIMENTS IN CONTROL.

Two orchards, one of pears and one of apples, which had been sprayed for the codling moth according to the recommendation of this bureau, show conclusively the advantage derived from this treatment.

The pear orchard shows more decided results than the apple orchard because of more thorough work with a power outfit at high pressure.

The second year's treatment on the pear orchard shows to advantage because of better work and timing of the applications.

Two years' observations have shown that three applications of arsenate of lead in the Santa Clara Valley at about 2 pounds to 50 gallons are necessary for pears and apples, except on Bartlett pears, where two would be sufficient.

The first application should be made just after the blossom petals fall, and the date may vary from early April to the first few days in May, depending upon the variety of fruit and the season; the second application should be made about from 2 to 3 weeks after the first application, and usually falls in June; the third application should be applied about from 3 to 4 weeks after the second, and usually falls in July.

Arsenate of lead can be used on pears along with the treatment recommended for pear-thrips larvæ, and the distillate-oil emulsion seems to give the poison a smoother surface tension so that it spreads more readily on the foliage and holds up longer in suspension while in the spray tank. The arsenate of lead should be mixed separately and added last to the spray tank after the distillate-oil emulsion and tobacco extract have been combined.

A power outfit should be used in spraying, maintaining 200 pounds pressure. Bordeaux nozzles equipped with an angle and used from a tower give the highest percentage of clean fruit.

## SUMMARY.

In the Santa Clara Valley of California there occurs one full generation and one partial generation of the codling-moth larvæ.

The following is a brief summary of the life cycle: The overwintered larvæ pupate from the middle of February until May, the moths issuing about six weeks later through a period extending from the latter part of March until the middle of June. Eggs are deposited about 3 days after emergence, and these hatch in about 12 days, the red ring appearing in 2 or 3 days and the black spot some 8 days later. The first-brood larvæ enter the fruit shortly after hatching and remain there for about 5 weeks. They are present in the fruit from the last week in April until the last week in July, a range of 3 months, or nearly three times their average larval life. After leaving the fruit the full-grown larva seeks some crevice in the bark on the main trunk or on the larger limbs of the tree and there spins its cocoon, transforming after a few days into a pupa. In confinement a great variation occurs in the time between spinning the cocoon and actual pupation, but in the field there is probably not nearly such a variation. The first-brood pupal stage averages 21 days, only half as long as the corresponding stage of the spring brood, a fact due, undoubtedly, to the considerably higher temperature influencing the former brood of pupæ. First-brood pupæ are present from about the middle of June until the middle of September, although the two years 1910 and 1911 (see figs. 31 and 39) show a considerable diversity on this point; for in 1910, the warmer of the two years, the first-brood pupæ were present three weeks earlier. Similarly the first-brood moths emerged just so much earlier in 1910. A fair proportion of the first-brood pupæ overwinter, and for this reason some individuals remain in the immature forms for 10 or 11 months. The first-brood moths begin to deposit eggs 3 days after issuing, and these eggs hatch in 11 days, or if the season is cold in 12 or 13 days. The red circle and black spot appear as in the first-brood eggs. The second-brood larvæ remain in the fruit about 50 days, and they are present from the latter half of July until the middle of October, a period of about 80 days, and thus shorter in comparison to the length of the larval stage than in the first-brood larvæ. This is accounted for by the shorter period of adult emergence, causing a shorter period of egg deposition in the first-brood moths as compared with that of the spring-brood moths. All larvæ of the second brood winter over and form the great bulk of overwintering larvæ. Doubtless if the fruit remained longer on the tree there would be a complete second brood possible, since so many varieties of apples and pears are picked before the end of September. In 1909 the second generation exceeded the first and this was a cold year, while in 1910 and 1911 the two generations were about equal in numbers, in spite of the fact that the former was a warm, the latter a cold, year. In 1910 there was good reason to expect a large second generation, considerably greater in relation to the first generation than in 1911, but the relative proportions of the two generations was not maintained in 1910. Consequently it may be inferred that the weather does not always exert great influence on the relative sizes of the two generations any more than a large number of individuals of the first brood does on the second.

The relative number of larvæ of the first brood that overwinter varies from year to year, but not entirely owing to influence exerted by the weather or the temperature.

The larvæ of the second brood are present in all but the earliest varieties of fruit, and it is necessary to combat them.

Weather conditions exert more influence on the spring emergence of moths than on the summer emergence.

The sex of the moth can be determined in the larval stage by the presence or absence of the two testes, which are black and in the male show through the skin on the dorsum of the eighth segment.

Three applications of the poison spray are necessary for the control of the codling moth in this locality. The first should be made immediately after the petals have dropped from the blossoms, the second should follow from 2 to 4 weeks later, and the third a month or 6 weeks after the second.

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